MOVING BEYOND PERCEPTUALLY FOCUSED WORD LEARNING STRATEGIES

by

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ABSTRACT

The current thesis aimed to explore potential contributing factors to the difficulty that young children may experience with moving past previously effective word learning strategies. The particular focus of this thesis was how children overcome an early tendency to focus on perceptual features as their basis for word meaning and the potentially greater difficulty that children may experience with linking words to relational concepts. These aims were explored through a series of experiments that looked at 2- to 5-year-olds' extensions of words (e.g. nouns, noun-noun compounds, verbs). Findings suggest: that children's difficulty with correctly attributing meaning to words which are primarily defined by relations is truly due to their relational nature and not their dynamic nature; that children's tendency to base word meanings on relations can be increased by explicitly highlighting the relation; that comparisons across more than one exemplars can help children attribute verb meaning to actions alone instead of an object-action combination; that inhibition ability may be a contributing factor in children's ability to overcome their focus on perceptual features when understanding word meaning; and that children with autism spectrum disorders may not make use of some processes that typically developing children employ to move beyond basing word meaning on shared perceptual features.

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CHAPTER ONE

LITERATURE REVIEW

Children learning their first language are gaining not just a tool for communication, but also a tool for understanding the world. Words can be used to label a great variety of things, including objects, features of objects, actions, and relations. Children come to learn that things which are the same have the same name, whether that be an object or an action. If two objects are ‘books’ then they are the same thing, i.e. their functions is to be read, they consist of pages of paper that are filled with written words. However one book may look very different from another. They may be different sizes / colours / hard back or paperback. But never-the-less they are all books and will be labelled as such. This is not an understanding that is necessarily present in young children. Rather young children appear to focus on perceptual similarity as their basis for whether two things are the same. And this is a method which serves them well in early childhood, as many things which are the same do indeed look the same. To continue our book example, many books do look very similar to one another. However this is often not the case. As children age they come to understand, as adults do, that it is not what something looks like which defines it, but what it does, e.g. a car and an aeroplane look very different, but are both vehicles, and a cat running looks very different to a spider running, but both are examples of running. But how do children overcome this initial tendency to focus on perceptual similarity in their word learning? In this thesis we will investigate how children overcome this word learning problem.

One of the ways in which children move away from a focus on perceptual similarity is by shifting their focus towards relational similarities (e.g. actions which link actors and objects when learning verbs). Therefore, linked to the above word learning problem is the issue that children find it harder to link words to relational concepts, such as transitive verbs than they do to non-relational concepts such as nouns. This we will also explore in this thesis. In the current chapter we will introduce literature which sets the scene for the experimental studies that will follow.

1.1. Why it might be harder to link words to relational concepts

Central to the idea that young children may find it more difficult to link words to relational concepts is the debate regarding why verbs (which are relational in nature) may be more difficult for children to acquire than nouns (which are non-relational in nature). Nouns tend to be acquired earlier than verbs in the English language (Gentner, 1982). And even in experiments where novel nouns and verbs are taught (Golinkoff, Hirsh-Pasek, Bailey & Wenger, 1992; Golinkoff, Jacquet, Hirsh-Pasek & Nandakumar, 1996; Childers & Tomasello, 2002), children appear to find the verbs more challenging to acquire (McDonough, Song, Hirsh-Pasek, Golinkoff, & Lannon, 2011). But why is this? What is it about verbs that makes them potentially harder to acquire than nouns? I will discuss a select number of theories that are pertinent to the aims of the current thesis. These include: differences in perceptibility of referents; the idea that meaning of nouns must be understood first; differences in imagability; the idea that verbs refer to relational concepts while nouns refer to non-relational concepts; and differing requirements for social and grammatical information.

To begin with then, some argue that the greater difficulty in acquiring verbs lies in the perceptibility of the referents (e.g. Golinkoff et al., 2002; Golinkoff & Hirsh-Pasek, 2008).

Nouns tend to refer to objects, which are static and easily perceivable, while verbs tend to refer to actions which are dynamic and fleeting and thus not as easily perceivable. It has also been argued that in order for children to understand the meaning of a verb in a given situation, they must first understand the meaning of the nouns (e.g. Kersten & Smith, 2002). For instance in a scene where a mouse eats some cheese, a child cannot learn the verb ‘eat’ until they have learned the nouns ‘mouse’ and ‘cheese’. When encountering a new word children may therefore be predisposed to direct their attention towards objects, rather than actions as potential referents (Kersten & Smith, 2002; Echols & Marti, 2004). Adding support to the potential importance of perceptibility it has been suggested that nouns may be acquired earlier then verbs because they are higher in imagability (Gentner & Boroditsky, 2001; Gentner, 2006; McDonough et al., 2011). Imagability refers to how perceivable, concrete and easy to individuate a word is. McDonough et al. (2011) found that imagability predicted age of acquisition over and above that of form class, with high imagability words being acquired earlier. It has also been argued that verbs are more difficult to acquire because they are relational in nature, i.e. they link an agent and an object via the action to which the verb refers (Gentner, 1982; Gentner & Boroditsky, 2001). Nouns on the other hand are non-relational in nature, tending to refer to single stand-alone objects or at least parts of objects. At the very least they can be interpreted without relating them to anything else in the scene. Golinkoff & Hirsh-Pasek (2008) also suggest that verb learning, unlike noun learning, may require (or at least benefit from) both social information in terms of the intent of the speaker (Akhtar & Tomasello, 1996; Poulin-Dubois & Forbes, 2002; Behrend & Schofield, 2006) and grammatical information in terms of where the novel verb appears in the sentence (Gleitman, 1990; Fisher, 2002; Lidz, Gleitman, & Gleitman, 2003; Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005). In fact it is highly likely that it is a combination of these suggested factors which makes understanding verbs a more troublesome word learning problem than understanding nouns. This would mirror the Emergentist Coaltion Model of word learning's (Hollich et al., 2000) approach that children are able to make use of a variety of different cues during word learning. This model holds that children are able to make use of mechanisms of global attention, cognitive constraints, and social-pragmatic factors during word learning. And that these different factors are relied upon to differing degrees during development. So, children are not influenced by just one factor during their word learning, but a number of them combined. Word learning appears to be a multi- factored problem and this is therefore also likely to be the case for verb learning.

In Chapter 2 of this thesis we will focus on two of the above reasons for why verbs may be more difficult to acquire than nouns, namely that verbs tend to be both dynamic and relational in nature compared to nouns. These two features are naturally confounded and we will attempt to draw them apart. We will do this by turning to noun-noun compounds (e.g. *book-shelf*, *cherry-pie*). The meaning of a noun-noun compound is not determined only by the identity of the constituent objects (e.g. the meaning of the nouns *book* and *shelf*, in the *book-shelf* example; or *pie* and *cherry* in the *cherry-pie* example), but also by the relation that exists between the constituents (e.g. a *book-shelf* is a *shelf* FOR storing *books*, and not for example a *shelf* that HAS a *book* attached to the side of it; a *cheery-pie* is a *pie* that HAS *cherries* in it, and not for example a *pie* FOR eating with *cherries*). In other words, just like verbs, noun-noun compounds are relational in nature. Importantly, though, noun-noun compounds are not necessarily dynamic in nature like verbs. Their relational components can be either static or dynamic in nature. Investigating children's understanding of different types of novel compounds will allow us to see whether children struggle with the relational nature of novel noun-noun compounds, independently of whether they refer to static or dynamic relations. In addition, we can see whether compounds with static relations might be easier to acquire than those with dynamic relations. In other words, the results will tell us whether it is the dynamic nature and/or relational nature that leads to difficulty in word acquisition. This will provide implications for the challenge of verb learning, and will help us to explore one of the central aims for this thesis, namely whether it is harder for children to link words to relational concepts.

Just as verbs are acquired later than nouns, relational information in compound words is acquired relatively late. Children show an ability to produce both existing and novel compounds before they are even 2-years of age (e.g., Clark, 1981; 1983) and appear to understand the structure of noun-noun compounds as consisting of a modifier and a head noun at 2-years (Clark, Gelman & Lane, 1985). However when it comes to the relational component of noun-noun compound meaning children's understanding appears to develop gradually. Nicoladis (2003) demonstrated a greater understanding in 4-year-olds, than 3-year-olds, that noun-noun compounds tend to refer to two interacting objects. Even between the ages of 6- and 9- years, children still sometimes show errors in their interpretation of compounds, describing a *book magazine* as 'a big magazine next to a little book' (Parault, Schwanenflugel, & Haverback, 2005). Furthermore children under 5-years tend to overuse HAS/LOCATED relations, both in their explanations of novel noun-noun compounds (Krott, Gagné & Nicoladis, 2009) and in their extensions of novel noun-noun compounds (Krott, Gagné & Nicoladis, 2010), suggesting a bias towards HAS/LOCATED relations.

1.2. The shape bias debate

The initial tendency to focus on perceptual similarity in word learning is strongly related to the shape bias debate in early noun learning. Adults tend to extend nouns to new instances on the basis of shared function of objects (e.g. Miller & Johnson-Laird, 1976). The shape bias debate relates to the question as to whether young children, like adults, focus on function when first learning names for objects or instead focus on shape. This is an issue that has divided researchers for many years. Clarke (1973) argued that it was the form / structure of objects which informed early word learning, while Nelson (1973) claimed that it was rather the object's function. Gentner (1978) conducted an experiment in which she pitted form versus function. Children were shown two objects which differed in form and function and heard them named with novel nouns. They were then asked to name a new object which shared the shape of one of the objects and the function of the other. Younger children chose to label the test object on the basis of shared shape rather than function, while children's focus on function increased with age. These findings showed strong support for an initial focus on shape in word learning.

Further research provided evidence for and against the shape bias hypothesis in early word learning. A number of studies supported Gentner's (1978) conclusion. Merriman, Scott, and Marazita (1993) asked children to extend a label given to a novel object. Younger children extended the label to an object which shared the original referents' shape, while older children extended the label to an object which shared the original referents' functions. Smith, Jones, & Landau (1996) provided evidence that not just shape, but perceptual features in general are privileged in young children's word learning. They showed that 3-year-olds extensions of novel names to novel objects were influence by the saliency of perceptual features, but not by function. Furthermore Graham, Williams, & Huber (1999) demonstrated that young children's focus on shape may be so strong that even when function is emphasised 3- and 5-year-olds may still choose shape as the basis for their label extensions.

However, other research has found that young children are able to make use of alternatives to shape in their label extensions. Kemler Nelson (1995) found that 3 – 6-year-old children will extend labels to objects which share the same function as the original referent over those that do not. Furthermore Kemler Nelson (1999) found that 2 – 3-year-old children will even privilege functional information over perceptual information when they have prior experience of the function of the objects involved. Similar findings from Kemler Nelson, Russel, Duke, & Jones (2000) show that 2-year-olds will extend labels on the basis of shared function, regardless of perceptual similarity, both when functions were demonstrated and when they needed to be discovered by the child (For further information on the conditions under which young children are most likely to make use of function in their noun extensions see Kemler Nelson, Frankenfield, Morris, & Blair (2000)). Research has also shown that young children are able to move beyond shape / perceptual features as their sole basis for noun extension when they are provided with conceptual information (Booth, Waxman & Huang, 2005). In this study, when told that an object was an artefact, infants extended its name on the basis of shape only. However, when told that it was animate, infants were able to extend its name on the basis of both shape and texture.

In summary, it is clear that in the case of noun-learning young children's initial focus appears to be on perceptual features of objects being labelled. However when alternative bases for noun extension are highlighted such as function, either by being made apparent through demonstration or through the child's own exploration / experience, even very young children are able to base their extensions on these alternatives. Therefore this additional information allows children to make noun extensions in a more adult-like way.

In Chapter 3 we consider whether highlighting the relation that exists between the constituents of noun-noun compounds will allow younger children to understand that the relation is an important component of meaning and a sensible basis upon which to extend compound-nouns. We are interested in discovering whether, just as in the noun learning literature discussed above, highlighting a more appropriate basis for extensions will allow young children to behave more like adults in their word learning. This speaks to both of our central themes: overcoming a focus on perceptual similarity in word learning and the increased difficulty of relational components of word meaning for young children.

1.3. Structural alignment and its potential benefits for verb learning

Acquiring the meaning of a word means developing a category of referents for the word. Thus, learning what the noun *chair* means requires a child to learn which objects the word can and cannot refer to, or learning what the verb *to kick* means requires the child to learn which actions/events the word can and cannot refer to. As the shape bias shows, children's understanding of what a novel word refers to is not necessarily the same as that of adults. While children might initially believe perceptual similarity to be the best basis for determining shared category membership for a novel noun, adults view function as a more accurate basis for category membership (e.g. Miller & Johnson-Laird, 1976).

Gentner (2003), in her 'Structural alignment' theory proposed that children can bootstrap themselves up to constructing more adult-like categories by using comparison across multiple instances. They argued that structural alignment allows children to shift their focus to relational components (e.g. function) as a basis for category membership. By viewing multiple exemplars children will be prompted to compare the conceptual representations of each exemplar that they have constructed in their mind with the implicit aim of finding correspondents between the two. While this comparison may initially be prompted by noticing perceptual similarities between the two exemplars, it is in fact relational commonalities that are preferentially highlighted by comparison processes (Gentner & Markman, 1997).

The idea that structural alignment may be beneficial in language acquisition is based on findings from analogy and similarity research (Gentner & Namy, 2006). For instance, Markman and Gentner (1993) showed a group of adults two pictures: One of a truck towing a car and one of a car towing a boat. When asked which feature of the second picture went with the car in the first picture, participants chose the car. However another group of adults who had first been asked to compare the pictures and rate them for similarity made a different choice entirely. They rather chose the boat from the second picture as the one which goes with the car from the first picture. Thus they chose the relational match.

These findings were extended to the realm of children's learning of linguistic categories. Comparisons between two objects can be triggered by either describing the objects or by labelling them both with the same name (Gentner & Namy, 2006). Gentner & Namy (1999) found that when 4-year-old children heard a picture of a single object (e.g. an *apple*) labelled with a novel noun and were asked to extend that noun to either a perceptual match (e.g. a *balloon*) or a taxonomic match (e.g. a *banana*) they chose the perceptual match. However when 4-year-olds heard two objects of the same category (e.g. an *apple* and a *pear*) labelled with the same novel noun and were asked to extend that noun to either a perceptual match (e.g. a *balloon*) or a taxonomic match (e.g. a *banana*) they instead chose the taxonomic match. This occurred even though the perceptual match was more perceptually similar to both of the exemplars than the taxonomic match. So if anything, participants had twice as much evidence for choosing the perceptual match when they saw two exemplars compared to a single exemplar.

Namy & Gentner (2002) provided evidence that hearing objects labelled with the same name promotes comparison processes. They investigated how extension of category membership might vary depending on whether two objects were labelled with the same name or a different name. For instance, participants were shown a picture of an *apple* and a *pear* and asked to extend category membership of the apple to either a perceptual match (*balloon*) or a taxonomic match (*banana*). If participants heard the two exemplar objects labelled with two different novel nouns, then they extended category membership to the perceptual match. However if they heard both exemplar objects labelled with the same novel noun then they extended category membership to the taxonomic match.

In Chapter 4 we will consider whether structural alignment processes which have been shown to be powerful for noun category learning may also be helpful for learning verbs. It has been suggested that, when young children view dynamic action scenes, it is difficult for them to focus on the action only as the defining feature of a verb instead of the combination of action and objects (Gentner & Boroditsky, 2001 and Imai et al., 2008). In fact this difficulty could also be part of the reason why children find verbs more difficult to acquire than nouns (see section 1.1. for a discussion on this). Even once they have learned that a particular verb can be used with a variety of objects and actors, they have difficulty extending this knowledge to other verbs as they are acquired. Each verb appears to be on its own developmental trajectory, with children learning which objects and actors each particular verb can be used with, a phenomenon termed “verb islands” (Tomasello, 1992; Tomasello, 2000). Structural alignment could be used to preferentially highlight relations in scenes, which might allow children to focus on the relational component of scenes, i.e. the actions, when learning new verbs.

There have been a variety of studies which suggest that for young children focusing only on the action when making sense of a newly encountered verb is difficult. It has been found that young children may view the agent used to perform an action as an important part of verb meaning (Behrend, 1990; Forbes & Farrar, 1993; Forbes & Poulin-Dubois, 1997). Furthermore, Kersten & Smith (2002) found that up to 4-years of age children appear to believe that the motion that an object performs is not as important as the identity of the object for the meaning of a newly learned verb.

In a replication of a procedure used in Imai, Haryu, & Okada (2005), Imai et al. (2008) investigated, amongst other languages, English speaking children's ability to map novel nouns and verbs appropriately, i.e. nouns onto objects and verbs onto actions. Three and five year-old children were presented with dynamic actions scenes involving an actor performing a novel action on a novel object. While viewing these scenes they heard either a novel noun or a novel verb. They were then required to extend the novel words to either a scene which maintained the object from the original referent but featured a different action or a scene which maintained the action but featured a different object. In the case that they heard a novel noun, the first choice would be correct (i.e. object maintained). In the case that they heard a novel verb, the second choice would be correct (i.e. action maintained). They found that while 5-year-olds could correctly extend both nouns and verbs, 3-year-olds could correctly extend only nouns. When it came to verb extensions the 3-year-olds appeared to believe that it was not enough for the same action to be present to constitute a new instance of a verb. Rather both the action and object acted upon needed to be present. The authors argue that rather than mapping the verb to the action component of the scene only, what they are actually doing is mapping the verb onto an object-action interaction i.e. they have mapped the verb onto a combination of the action and the object acted upon, and both these components need to be present in order to constitute a new instance of a verb.

In Chapter 4 we aimed to investigate the potential benefits of structural alignment processes in children's verb learning. In particular we were interested in the benefit of a single additional exemplar and how the contents of this additional exemplar would affect any potential benefit. We were also interested in whether this additional exemplar would be enough to break the object-action interaction mapping engaged in by 3-year-olds and allow them to map verbs correctly to the action component of a scene only. With regard to the central aims of the thesis, the study presented in this chapter would shed light on whether structural alignment could act as a means for allowing young children to shift their focus away from perceptual similarity of objects involved when trying to make sense of novel verbs and rather focus on relations between actor and objects.

1.4. Executive function abilities and their effect on ability to focus on relations during word learning

Adults use shared function as the basis for their noun extensions (e.g. Miller & Johnson-Laird, 1976) and therefore base their noun categories on shared function. As discussed previously, young children on the other hand tend to base their noun extensions on perceptual similarity (e.g. shared shape). Structural alignment processes (see section 1.3. for a discussion of literature relating to structural alignment) have been proposed to allow young children to shift their focus from perceptual similarities towards relational similarities such as function in category learning.

As discussed, structural alignment processes are initially prompted by noticing perceptual similarities between possible members of a category, which then highlight deeper relational commonalties, such as function. This allows young children to extend category membership in a style more akin to that of adults. However perceptual similarities are the first thing children notice in structural alignment and making extensions on the basis of perceptual similarity is an early developed word learning strategy, and indeed one which will have served them well in their early linguistic development. Objects of the same kind often look very similar. We suggest that children may need to first inhibit a prepotent tendency to construct categories on the basis of perceptual similarity in order to make use of structural alignment. After first noticing perceptual similarities children need to 'hold fire' and look at the relational commonalities, and choose to use these as the basis for what constitutes a member of a given category over perceptual similarities. In Chapter 5 we investigate the potential presence of an inhibitory component in structural alignment. This links to the central aims of the thesis as it investigates a potential factor that may be involved in children overcoming an early tendency to focus on perceptual features during word learning.

Alongside attention switching and working memory, inhibition forms part of a collection of goal directed adaptive processes known as executive function abilities (Hughes, Graham, & Grayson, 2005). Executive function abilities are not fully formed at birth. They manifest at different ages and show improvement with age, particularly during the pre-school period (Carlson, 2005; Garon, Bryson & Smith, 2008; Hughes & Ensor, 2011). We shall now briefly review literature looking into the development of inhibition abilities as well as working memory. The latter will be important for the experiment in Chapter 5 because we also assessed working memory in order to differentiate between a potential role for inhibition and one for general executive function ability in early word learning.

Tasks that assess children's inhibition capabilities test their ability to inhibit a prepotent response, that is to stop themselves from doing one thing and instead do another, e.g. act in accordance with a game rule, rather than act as they normally would. Children's ability to inhibit a prepotent response such as reaching for something they want is often assessed by delay of gratification paradigms (Garon, Bryson & Smith, 2008). In these paradigms children are required to withhold a response in order to get a greater reward (e.g. two sweets if they wait, one if they don't). Improvements in amount of time children are able to delay their response has been found as they progress through the preschool years (Kochanska, Murray, Jacques, Koenig, & Vandeceest, 1996; Kochanska, Murray, & Harlan, 2000; Carlson, 2005, Garon, Bryson & Smith, 2008). Similar improvements with age during this period were found for another type of delay of gratification task, namely one in which children must choose between having a smaller reward immediately or a larger reward at a later time (Thompson, Barresi, & Moore, 1997; Moore, Barresi, & Thompson, 1998; Lemmon & Moore, 2001; Lemmon & Moore, 2007, Garon, Bryson & Smith, 2008).

Some inhibition tasks involve holding an arbitrary rule in mind and acting in-line with this rule. An example is the Grass-Snow task in which a child is required to point at a green piece of paper when they hear "snow" and point at a white piece of paper when they hear "grass", i.e. in contrast to what would be semantically expected. These types of inhibition tasks are labelled "complex response inhibition tasks" by Garon, Bryson, & Smith (2008). Once again children's ability to succeed at these tasks improves during the preschool period (Gerstadt, Hong, & Diamond, 1994; Diamond & Taylor, 1996; Keenan, 1998; Diamond, 2001; Diamond, 2002; Simpson, Riggs, & Simon, 2004; Carlson, 2005, Garon, Bryson & Smith, 2008), just as it does with tasks that involve inhibiting following verbal instructions (Keenan, 1998; Diamond, 1991; Cole & Mitchell, 2000; Dowsett & Livesey, 2000; Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002; Jones, Rothbart, & Posner, 2003; Carlson, Moses, & Claxton, 2004; Carlson, 2005, Garon, Bryson & Smith, 2008).

Working memory refers to the ability of an individual to hold information in mind and to update it, with the latter ability developing later (Garon, Bryson & Smith, 2008) (See Baddeley (1986); Baddeley (2000); and Baddeley (2002) for the most widely accepted model of working memory). There are a variety of experimental task that are used to assess children's working memory abilities. These include delayed response tasks which are used with children under two years and involve remembering which of a number of locations a toy is hidden in (Garon, Bryson & Smith, 2008). Over the first two years, children show an increase in both the number of items they can hold in mind and the length of time they can hold them for (Diamond and Doar, 1989; Pelphrey & Reznick, 2002; Pelphrey et al. 2004; Garon, Bryson & Smith, 2008). The retention abilities of children aged above 2-years tend to be assessed with memory span task (e.g. digit span; word span etc; Garon, Bryson & Smith, 2008). The number of items children can hold in mind on these span tasks has been found to improve between the ages of 3- and 5- years (Davis & Pratt, 1995; Keenan, 1998; Gathercole, 1998; Gathercole, 1999; Kemps, Rammelaere, & Desmet, 2000; Luciana, 2003; Ewing-Cobbs, Prasad, Landry, & Kramer, 2004; Bull, Espy, & Senn, 2004; Espy & Bull, 2005; Garon, Bryson & Smith, 2008). As stated, the ability to update information held in working memory develops later. This ability is assessed in children via the use of self ordered pointing tasks, which involved keeping track of which locations have and have not been searched when looking for concealed objects (Garon, Bryson & Smith, 2008). Just as with the span tasks improvements in performance on self-ordered pointing tasks occur between 3- and 5-years of age. Improvements occur in both accuracy and number of items that can be kept track of (Diamond, 1991; Luciana & Nelson, 1998; Luciana & Nelson, 2002, Luciana, 2003; Ewing-Cobbs et al., 2004; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Garon, Bryson & Smith, 2008).

1.5. Autism and category learning

One population that may find it harder than most to overcome a focus on perceptual similarity in their word learning are children with autism. Autism is a developmental disorder, diagnosed by the presence of deficits in social communication / social interaction and the presence of restricted and repetitive patterns of behaviour, activities or interests (American Psychiatric Association, 2013). It has initially been suggested that individuals with autism may have difficulty in forming categories (Menyuk, 1978; Fay & Schuler, 1980; Jackendoff, 1983, cited in Tager-Flusber, 1985a). However, when this hypothesis was put to the test, children with autism proved themselves capable of forming categories (Tager-Flusber, 1985a; Tager-Flusber, 1985b; Ungerer & Sigman, 1987). Once it was established that individuals with autism did form categories, research turned to whether they did so in the same way as typically developing individuals. Findings have thus far suggested that they do not.

Differences between the categorisation abilities of individuals with autism and typically developing individuals have been found in a number of studies. Bott, Brock, Brockdorff, Boucher, and Lamberts (2006) demonstrated that individuals with autism formed categories based on fewer dimensions than typical controls. Soulieres, Mottron, Saumier, and Larochelle (2007) found no influence of category membership on individuals with autism's decisions in a same / different task. Furtheremore, Soulieres, Mottron, Giguere, & Larochelle (2011) found that individuals with autism were slower to reach the same level of categorisation accuracy when learning novel categories.

Of particular interest for the present thesis are findings that individuals with autism may be using different underlying processes when forming their categories. They do not necessarily construct prototypes to use as a basis for category membership. They rather appear to construct a set of necessary and sufficient rules for whether something can be considered an instance of a particular category (see work by Klinger & Dawson (2001) and Plaisted (2000)). Furthermore, they have difficulty abstracting concepts from complex information (Minshew, Meyer, and Goldstein, 2002) and categorising atypical or complex objects (Gastgeb, Strauss, & Minshew, 2006).

Klinger & Dawson (2001) highlight parallels between their assertion that individuals with autism do not construct prototypes and the suggestions of weak central coherence theory (Frith, 1989; Frith & Happe, 1994; Happe, 1999) that they have difficulty drawing together information into a coherent whole. Weak central coherence theory emphasises that individuals with autism tend to focus on details at the expense of the whole. This can lead to better performance than neuro-typical controls on tasks where such a focus is beneficial, such as the Wechsler Block Design task (Shah & Frith, 1993). Weak central coherence theory has been suggested as resulting in a different cognitive style, with a different pattern of strengths and weaknesses than would be found in typically developing individuals.

In an attempt to further investigate potential ways in which children with autism may differ in the processes they employ when learning categories, Chapter 6 investigates whether children with autism engage in structural alignment when constructing their categories (see section 1.3. for a discussion of literature relating to structural alignment) and explores how weak central coherence might act as an explanation not just for absence of prototype formation, but also for other differences in category learning. This will enable us to see whether children with autism are able to employ a process which typical children use to overcome their focus on perceptual similarity when learning categories/words.

1.6. Summary

In summary, this thesis aims to investigate the ways in which children overcome a tendency to focus on perceptual features / similarity at the expense of more pertinent information during word learning in the preschool period and the additional challenges posed by relational concepts. In Chapter 2 we will investigate whether it is the relational or dynamic nature of noun-noun compounds which proves challenging for young word learners and discuss implications for why verbs prove more difficult to acquire than nouns. In Chapter 3 we will investigate whether highlighting relational components helps younger children understand their importance in noun-noun compound meaning. In Chapter 4 we will investigate whether structural alignment processes can aid young children in focusing only on the relational component (i.e. action) as the determinant of verb meaning. In Chapter 5 we explore a potential role for executive function abilities, namely inhibition, in allowing children to focus on relations and base their word extensions on relational information. Finally in Chapter 6 we will investigate whether children with autism make use of structural alignment in their formation of categories.

CHAPTER TWO

THE CHALLENGE OF RELATIONAL REFERENTS IN EARLY WORD INTERPRETATIONS: EVIDENCE FROM NOUN-NOUN COMPOUNDS

Abstract

Research suggests that verbs are more difficult to acquire than nouns partly because they refer to relational and dynamic referents compared to non-relational and static referents. However it is unclear which aspect actually proves challenging. Because relational and dynamic aspects are generally confounded in nouns and verbs, we focused on noun-noun compounds, for which this is not the case. We created novel compounds (e.g. *wug binto*) with relational meaning components that were either static (a *binto* that HAS a *wug* attached to it) or dynamic (a *binto* that is FOR a *wug*). Two-to-five year-olds and adults were asked to generalise compounds to one of two object pairs: either correctly to an object-pair combined via the same relation (HAS or FOR) as the training item but with perceptually dissimilar objects (e.g. different colour), or incorrectly to an object-pair combined via a different relation (FOR instead of HAS or vice versa) but with the same objects as the training item. Results support a developmental focus shift from non-relational to relational aspects, but not from static to dynamic aspects. This suggests words like verbs that are relational and dynamic may be more difficult to acquire because of their relational rather than dynamic nature.

2.1. Introduction

A key part of early language acquisition involves learning words which refer to objects and words which refer to relations between objects. But is it equally easy / difficult to link words to objects and to relations between objects? Research into words that refer to objects and relations suggests that this is not the case. Nouns typically refer to objects, while verbs typically refer to relations between objects, i.e. actions that relate actors and objects. When examining children's early vocabularies, it has been found that nouns often dominate over verbs (e.g., Genter, 1982; for a recent review see Waxman et al., 2013). While that by itself is not evidence that linking words to relations is harder than linking words to objects, Gentner and colleagues have pointed out that the underlying concepts of nouns and verbs are very different and that this difference very likely makes the acquisition of verbs more challenging than that of nouns (e.g. Gentner, 1982; Gentner & Boroditsky, 2001; Golinkoff & Hirsh-Pasek, 2008).

One difference between actions and objects is that actions are intrinsically relational in nature (e.g., Gentner & Boroditsky, 2001; Golinkoff & Hirsh-Pasek, 2008). Take the example of 'kicking': the verb 'kicking' cannot be understood without reference to an agent (the boy) and an object (the ball). In contrast, objects (and nouns, which refer to objects), i.e. living beings such as dog or fish, and artefacts such as bed, spoon, or computer, are usually not thought of as being relational. The reason for that is that they can be defined in a non-relational way, which is by their perceptual features. For instance, a *bed* is an object that typically has a frame, four legs, a mattress, a pillow and a duvet etc. Looking more closely at objects, however, it turns out that they have a relational component as well, namely a function. For instance, the function of a *bed* is for somebody to sleep on it. For adults, the function turns out to be the most important part of the meaning of words that refer to objects, i.e. concrete nouns (e.g. Miller & Johnson-Laird, 1976). However, function and perceptual features are highly correlated. One can therefore learn what the word *bed* refers to by learning the non-relational component, i.e. by learning how a bed typically looks like. This can contribute to why young children can understand and use nouns more easily than relational words like verbs.

Apart from the relational difference between objects and actions, actions are also ephemeral and more difficult to individuate compared to objects (e.g. Gentner, 1982; Gentner & Boroditsky, 2001; Imai et al., 2008). Objects are perceptually relatively stable. That is the object's shape, size, and colour etc. usually remain the same over time. That makes them easy to individuate. In fact it is so easy that children have been shown to individuate concrete objects prelinguistically (e.g., Spelke, 1990; Wilcox & Baillargeon, 1998). In contrast, actions are dynamic in nature. An action is often only briefly observable, and it is difficult to decide which aspects of a dynamic event a verb refers to. For instance, if presented with the verb 'kicking' and a scene where a boy runs, kicks a ball, and the ball shoots away, the child needs to decide whether the running or the shooting away might be part of 'kicking'. In other words, the child needs to decide whether one can 'kick' something without running and whether the object that one kicks has to move in order for the action to be 'kicking'.

In line with these conceptual arguments, there is experimental evidence that linking words to actions is indeed difficult for young children, and more difficult than linking words to objects. One finding is that, when initially interpreting the meaning of a novel verb, i.e. a word referring to an action, younger children tend to focus rather on the objects involved in an action instead of how those objects are related by the action. For instance, Behrend (1990) found that 3- and 5-year-old children failed to generalise a novel verb given to a novel action in about 40% of the cases when the instrument used to perform the action was changed, while adults only failed to make the generalisation in 13% of the cases (see also Forbes & Farrar; 1993). Furthermore, English and Japanese 5-year-olds, but not 3-year-olds are able to generalise a novel verb to a different event if the object being acted on changes, while even 3-year-olds are able to correctly generalise a novel noun to a different event (Imai, Haryu, & Okada, 2005; Imai et al., 2008).

The question arises whether it is the dynamic nature of word referents or their relational nature that poses a challenge during early word learning. This question is difficult to answer when investigating verbs and simple nouns because the two conceptual dimensions are heavily confounded in the child vocabulary. That is children's nouns tend to refer to static and non-relational concepts, while their verbs tend to refer to dynamic and relational concepts. In the current study we therefore turn to a word type where relational and dynamic aspects are not confounded and that therefore allows us to investigate whether it is dynamic or relational referents that prove challenging during early word learning, namely noun-noun compounds.

Noun-noun compounds have relational components that are not overtly expressed and therefore need to be inferred from experience with the referents. To illustrate, a child who has not developed a meaning of the compound *cheesecake* or *toybox* needs to understand that a *cheesecake* is a cake that HAS cheese in it and not, for instance, a cake that is to be eaten with cheese (i.e. a cake FOR cheese), and a *toybox* is a box FOR toys and not, for instance, a box that HAS a toy attached to it. They also have to understand that a *cheesecake* can be any cake that HAS any type of cheese in it, and a *toybox* can be any type of box that is used FOR storing any type of toy. Therefore, it is the relation between the constituents that defines a compound, while the exact identity of the constituents (e.g. the colour or size of the box or the type of toys) is not part of the compound's meaning. Importantly and in contrast to verbs and nouns, the relational component in compounds can be either dynamic as in the case of a FOR relation or static as in the case of a HAS relation (N.B. The dynamic nature of the FOR relation stems from the fact that if one wants to demonstrate the relation, one needs to perform an action). Therefore, investigating children's acquisition of compounds allows us to disentangle a developmental shift in focus from non-relational towards relational aspects within word learning from a shift from static towards dynamic aspects.

Children produce noun-noun compounds very early. First productions of existing and novel compounds often appear in speech prior to the second birthday (e.g., Clark, 1981; 1983), and two-year-olds generally understand the roles of the two nouns as that of the modifier and the head (Clark, Gelman & Lane, 1985). They also use novel compounds in a sub-categorisation task in an impressively adult-like manner: Clark, Gelman & Lane (1985) found they produced compounds significantly more often when labelling subcategories related by inherent (e.g. *pumpkin house* for a house made out of pumpkin) or semi-inherent properties (e.g. *camel book* for a book with a camel drawn on the cover) than for subcategories related by accidental properties (e.g. *duck chair* for a chair with a duck sitting on it). However, children's understanding of the relational component of noun-noun compounds develops gradually. For example, 4-year-olds display a stronger understanding than 3-year-olds that noun-noun compounds usually refer to two interacting objects in contrast to two objects accidentally located next to each other (Nicoladis, 2003). And even 6-9-year-olds occasionally interpret compounds such as *book magazine* as 'a big magazine next to a little book' (Parault, Schwanenflugel, & Haverback, 2005). Furthermore, Krott, Gagné & Nicoladis (2009) and Krott, Gagné & Nicoladis (2010) found that children do not have the same understanding of relations in compounds as adults. Children tend to interpret compounds as having HAS/LOCATED relations rather than FOR relations while for adults both kinds of relations are equally possible. This was evident in 4-5-year-olds' explanations of familiar compounds and in 2- and 3-year-olds' interpretations of novel compounds (e.g. *kig donka*). These results are even more surprising given the fact that FOR relations easily outnumber other relation in the children's compound vocabulary (Krott et al., 2009).

In the present study we thus investigated initial interpretations of novel noun-noun compounds. We were interested in whether during development children shift their focus from static to dynamic aspects of compounds' referents or from non-relational to relational aspects, or if both co-occur. Through this we aimed to disentangle a developmental focus shift from non-relational to relational features from a shift from static to dynamic features. We tested whether children between two and five years as well as adults generalise a novel compound to a new instance on the basis of shared relational information or on the basis of shared perceptual identity of the constituent objects. Participants generalising on the basis of shared relational information would generalise a compound from a familiar instance to a novel instance that shared the same HAS or FOR relation that relates the constituent objects, irrespective of the identity of the constituent objects in the two instances. For example, the participant would generalise the compound from one instance where the two constituent objects were attached to each other (= HAS relation) to another instance where the two constituent objects were attached to each other (=HAS relation), even though the objects in the two instances are different colours (e.g. from Panel C to Panel D of Figure 2.1). Participants generalising on the basis of shared perceptual identity of the constituent objects would generalise a compound from a familiar instance to a novel instance on the basis of the identity of the constituent objects, irrespective of the relation between the constituent objects. For example, the participant would generalise the compound from one instance to another where the constituent objects of the two instances are the same, but the relation by which the

Part 1 – training of object labels	  A) “This is a kig, and this is a kig” B) “This is a donka, and this is a donka”
Part 2 – training of compound labels	 C) “This is a kig donka” (Version 1 HAS relation)
Part 3 – testing compound understanding	  D) Version 2 HAS relation E) Version 1 FOR relation “Can you show me a kig donka?”

Figure 2.1. Example of procedure for Experiment 1. Extension of the compound-noun to Panel D would represent extension to an object-pair which shares relation type with the original referent, but not colour of constituent objects i.e. extension on the basis of shared relation. Extension of the compound-noun to Panel E would represent extension to an object-pair which shares colour of constituent objects with the original referent, but not relation type i.e. extension of the basis of shared identity of constituent objects.

constituent objects in each instance are combined differs, e.g. they are related by a HAS relation in the training item and by a FOR relation in the test item (for example, from Panel C to Panels E of Figure 2.1).

We expected adults to generalise on the basis of shared relational information because, as explained above, the relations, not the perceptual identity of the objects are the key aspect of compound meaning. Findings from noun and verb learning predict a developmental shift from a focus on non-relational / static information to a focus on relational / dynamic information for compounds. By varying the type of relation, namely static HAS relations versus dynamic FOR relations, we were able to tell whether the shift is a shift towards relational information, or rather a shift towards dynamic information, or indeed if both co-occur. A shift from non-relational towards relational information would mean that younger children tend to choose on the basis of perceptual identity of constituent objects while older children tend to choose on the basis of relational identity. A shift from static to dynamic information would mean that children become increasingly better with age at generalising FOR relations (which are dynamic) relative to HAS relations (which are static).

We carried out a main experiment (Experiment 1) along with two control experiments (Experiments 2 and 3). In the main experiment we pitted the generalisation of a novel compound on the basis of perceptual identity of constituent objects against generalisation on the basis of relational identity. The two control experiments ruled out alternative explanations for the performance of the younger participants in the main experiment such as high processing demands.

2.2. Experiment 1

2.2.1. Method

2.2.1.1. Participants. Participants were 14 two-year-olds (mean age 33 months, *SD*=2.8, 7 males), 26 three-year-olds (mean age 43 months, *SD*=3.8, 16 males), 20 four-year-olds (mean age 52 months, *SD*= 3.7, 11 males), 21 five-year-olds (mean age 64 months, *SD*=2.8, 9 males), and 20 adults (mean age 35 years, *SD*=12.6, 12 males). The children were recruited from nurseries and schools in the West Midlands area of the United Kingdom. Permission for them to participate was granted by either the head teacher or the owner of the nursery. Parental consent was obtained when requested by the head teacher / nursery owner. Adult participants were also recruited from the same region. All participants were native speakers of English, and for the majority this was their only language. The exceptions were two 4-year-olds and three 5-year-olds who spoke an additional language, although all spoke fluent English. There was no indication that participants who also spoke another language performed any differently from those who spoke only English. We therefore included those children in our analysis.

2.2.1.2. Design. This experiment had a mixed experimental design. The independent variables were the between-subjects variable Age group (2, 3, 4, and 5-year-olds and adults) and the within-subjects variable Relation type (FOR vs. HAS). The dependant variable was the number of correct responses during test phase (Part 3).

2.2.1.3. Materials. Four familiar objects were used as distracters in the first part of the procedure: a pen, a pencil, a spoon, and a teddy bear. Twelve novel objects were given twelve novel names (e.g. *kig, sav, mov*). There were two different colour versions of each object to make it clear that the nouns were not proper names, but instances of categories. A complete list of the objects can be found in Appendix A.

Objects were paired so that there would be two colour versions of each pair (e.g. for the *kig donka,* a purple *kig* and an orange *donka* were paired for version 1, and a orange *kig* and a blue *donka* were paired for version 2). See Panels A and B of Figure 2.1 for an example. Within object-pairs, objects could be combined via a HAS relation where the one object was permanently attached to the other. This was designed to imitate real life compound-nouns which are defined by one object having another attached to it, e.g. *clocktower, pearlring, keyboard, motorboat*. Object-pairs could also be combined via a FOR relation where one object is used for the other. This was designed to imitate real life compound-nouns which are defined by one object being used for the other e.g. *candlestick, toy box, egg cup, biscuit tin*. A complete list of the object-pairs can be found in Appendix B.

2.2.1.4. Procedure. All participants were tested individually in a quiet room or corner of a room. The procedure involved three parts which took place over two consecutive days. On the first day participants completed parts 1 and 2. In Part 1 participants learned the names of the individual novel objects that would make up the object-pairs for the compounds in Part 2. In Part 2 participants learned the compounds together with the corresponding object-pairs. On the second day, for Part 3 participants were asked to extend each compound-noun to one of two new exemplars. Either to an object-pair, whose constituent objects were combined via the same relation but differed in colour to those of the original referent (a correct choice), or to an object-pair whose constituent objects were identical in colour to those of the original referent but were combined via a different relation. The following sections describe the details of the three parts.

Part 1: Training of labels for constituent objects (Day 1). This involved participants learning the names of each of the novel objects which would form the object-pairs for the compounds in Part 2. The child was sat at a desk opposite the experimenter and told “I’m going to show you some toys and teach you the name for those toys, is that okay?” The experimenter then showed the participant the first object of a particular object-pair, in both colour versions. For example for the compound *kig donka*, the child would be shown both the purple *kig* and the orange *kig* (see Panel A of Figure 2.1). The experimenter then said “Look at this, this is an X, and this is an X. They are both X. Do you like the X? Can you say X?” (X replaced with the name of the object, e.g. *kig*). Participants therefore heard the novel word five times. The experimenter would then wait for the participant to repeat the name of the object and subsequently praise them for doing so. The experimenter then showed the participant the second object of the object-pair in both colours (e.g. the orange *donka* and the blue *donka*, see Panel B of Figure 2.1), introducing the objects in the same way as the first object.

Having introduced the constituent objects of an object pair, the experimenter would test whether the participant remembered which object is which. He placed one exemplar of both constituents as well as a distracter item randomly on the table. The exemplars that were shown were always the ones used for introducing the compound in Part 2 of the procedure (e.g. the purple *kig* and the orange *donka*). The distracter item was decided at random. The experimenter then said “show me an X” (X being one of the novel objects, e.g. *kig*). The novel object that he asked for was again decided at random. If the participant responded correctly they were praised. If the participant failed to respond, the experimenter said “Can you show me an X, do you know which one is an X?” If the participant responded incorrectly they were again presented with the names for the novel objects, all objects were removed and the identification task was repeated using a different distracter and different arrangement of objects.

Part 1 was repeated for all the object-pairs. Participants were not allowed to proceed onto Part 2 unless they had successful completed Part 1. This ensured that they had learned the names of the constituent objects which would be used to make up the object-pairs for the compounds in Part 2. It was very rare for children to fail to identify the novel object on their first attempt and younger children showed no more difficulty in doing so than older children.

Part 2: Training of compound labels for novel object-pairs (Day 1). After having been introduced to all constituent objects in Part 1, the participant was introduced to the combinations of these constituents and the compounds that referred to them. For each compound, the participant was shown a version 1 object-pair combined via either a HAS relation (i.e. one of the objects HAS the other attached to it) or a FOR relation (i.e. one of the objects is functionally related to the other, e.g. used FOR storing the other object inside it). For example participants might be presented with a version 1 HAS relation *kig donka* (an orange *donka* that HAS a purple *kig* attached to it). See Panel C of Figure 2.1. Whenever a HAS relation was presented, the constituent objects were permanently attached to each other and presented as such, while for the FOR relations, the constituent objects were separate and it was demonstrated how they functionally relate to each other (for a complete list of object pairs and relations see Appendix B). In order to get as equal attention as possible for all object-pairs, each object-pair was handled by the experimenter very similarly and for the same amount of time, regardless of whether it was a HAS or FOR relation object-pair. In other words, a HAS relation object pair was not simply put in front of the participant, but presented in an engaging way by holding and rotating it in different ways. As the object-pair was presented the experimenter then said "this is an XY, isn't the XY interesting, do you like the XY, can you say XY?" (XY replaced with the name of the object-pair, e.g. *kig donka*).

This procedure was repeated for all of the version 1 object-pairs. Each participant was only shown one relation (HAS or FOR) for each object-pair, but always saw three FOR relation object-pairs and three HAS relation object-pairs. Whether a participant saw a FOR or HAS relation for a particular object-pair was counterbalanced across participants. Finally, the participant was thanked for their help and given a sticker.

Part 3: Testing understanding of the meaning of the novel compounds (Day 2). On the following day participants completed the testing phase. Here they were introduced to two potential targets for extension of the compound-noun they heard the previous day; one object-pair which shared the same relation but not object colours of the original referent, and one which shared object colours but not relation type. The participant was told “I’m going to show you some toys and we’ll see if you know the names of those toys, is that okay?” Participants were then shown the version 2 object-pair which corresponded to the version 1 object-pair that they had been shown the previous day, i.e. a pair with the same relation as that seen the previous day but with constituent objects in different colours. For instance, if the participant had been shown a version 1 *kig donka* with a HAS relation (i.e. orange *donka* that HAS a purple *kig* attached to it) the previous day (see Panel C of Figure 2.1), they would be shown a version 2 *kig donka* with a HAS relation (i.e. blue *donka* that HAS a orange *kig* attached to it; see Panel D of Figure 2.1). Extending the compound-noun to this object-pair would indicate generalisation on the basis of shared relation type. The experimenter introduced the object-pair with “Look at this, have a good look at it”. They were also shown the version 1 object-pair with the different relation to that seen the previous day but whose constituent object colours were the same. Thus, if the participant had been shown a version 1 *kig donka* with a HAS relation (i.e. orange *donka* that HAS a purple *kig* attached to it) the previous day, they would be shown a version 1 *kig donka* with a FOR relation (i.e. orange *donka* that is used FOR storing a purple *kig*; see Panels E of Figure 2.1). Extending the compound-noun to this object-pair would indicate generalisation on the basis of shared perceptual identity of constituent objects. The experimenter again said "Look at this, have a good look at it". As in the training phase, whenever an object-pair with a HAS relation was shown, it was presented with the constituent objects already permanently connected. Whenever an object-pair with a FOR relation was shown, constituent objects were separate and the experimenter demonstrated how they functionally related to each other. In order to make HAS and FOR relation object pairs as equally interesting and engaging as possible, each object-pair was handled by the experimenter very similarly and for the same amount of time, regardless of whether it was a HAS or FOR relation object-pair. That is, a HAS relation object pair was not simply put in front of the participant, but presented in an engaging way by holding and rotating it in different ways. The order in which the two object-pairs were presented was counterbalanced across participants.

The experimenter would then place both object-pairs on the table in a random order and say "can you show me an XY" (XY replaced with the name of the object-pair, e.g. *kig donka*). The participant would then point to one of the object-pairs and was praised for doing so. Pointing at the object-pair which shared the same relation as the one seen the previous day would be a correct selection. Part 3 was repeated for all the object-pairs introduced the previous day. Finally the participant was thanked for their help and given a sticker.

Where the participant was an adult, the procedure was kept identical to that described above, with the following exceptions. Adult participants were told that they were to take part in a study about language acquisition, which would involve them learning the names of some novel objects. They were not praised for making choices and they did not receive a sticker for taking part.

2.2.2. Results

Selection of the object-pair that had the same relation as the original referent of the compound-noun was considered a correct response. Figure 2.2 displays the results. The number of correct selections was analysed with a split-plot ANOVA with Age group (2-years vs. 3-years vs. 4-years vs. 5-years vs. Adult) as a between participants factor and Relation type (FOR vs. HAS) as a within participants factor. The results indicated a significant main effect of Age group ($F(4,95) = 34.8$, $p < .001$, partial $\eta^2 = .594$; alpha level of .05 is used throughout study) showing that selection of the correct object-pair increased with age.

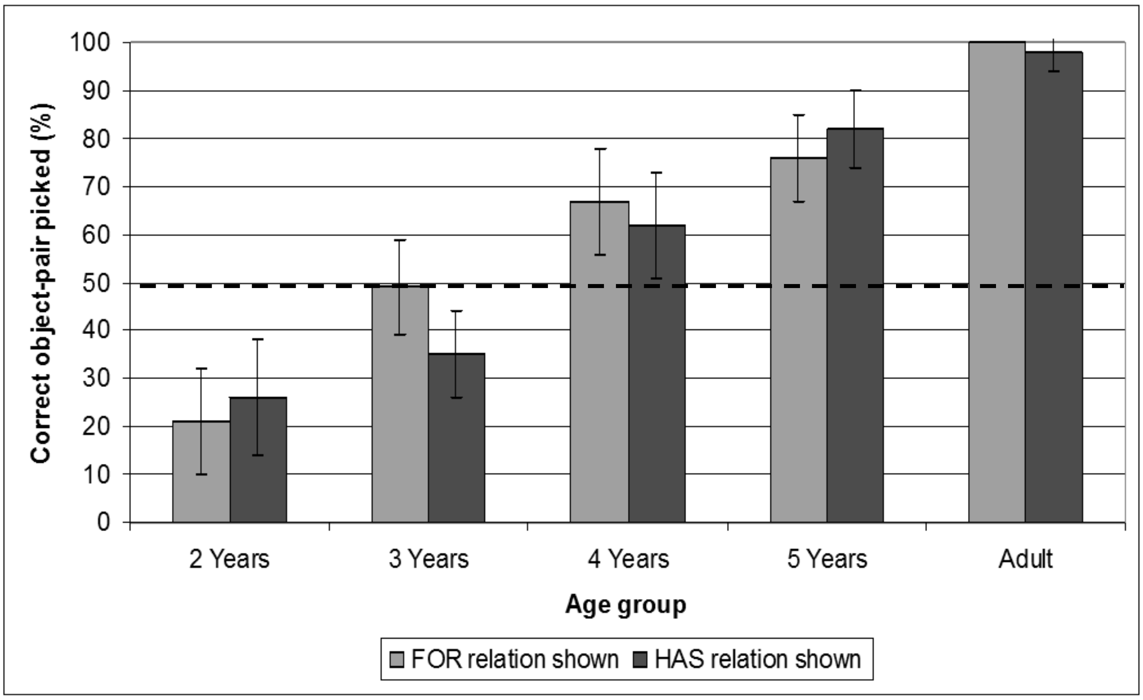


Figure 2.2. Experiment 1: The effect of age group and relation type on participants' ability to correctly generalise a novel compound-noun used to label a novel object-pair on the following day (50% line marks chance level). A correct choice was the object-pair that shared the relation with the training item and not the pair that had perceptually similar constituent objects to the training item. Error bars represent standard error.

Tukey HSD post-hoc tests revealed that selection of the correct object-pair differed significantly between all age groups apart from 2- and 3-year-olds and 4- and 5-year-olds ($p < .05$). There was no significant main effect of Relation type ($F(1,95) = 0.4$, $p = .550$, partial $\eta^2 = .004$), suggesting that overall performance did not differ between relation types. The interaction between Age group and Relation type was also not significant ($F(4,95) = 1.9$, $p = .324$, partial $\eta^2 = .047$).

Figure 2.2 also shows that the selection of the correct object-pair occurred at above chance level (i.e. more than 3 out of 6 correct responses) for 4-year-olds, 5-year-olds and Adults: 4-year-olds: $t(19) = 2.4$, $p = .025$; 5-year-olds: $t(20) = 6.4$, $p < .001$; Adults: $t(19) = 40.0$, $p < .001$. In contrast, 2-year-olds' and 3-year-olds' selections occurred below chance level, even though significantly only in case of 2-year-olds, $t(13) = -7.3$, $p < .001$, not 3-year-olds, $t(25) = -1.4$, $p = .163$.

An additional analysis checked for differences between the object-pairs. We conducted a repeated measures ANOVA to investigate the effect of the Object-pair type (coodle tez vs. kig donka vs. koba sav vs. rinta dax vs. tidgy mov vs. wug binto) on participants' performance. The test indicated no significant effect of Object-pair type ($F(5, 495) = 2.0$, $p = 0.089$, partial $\eta^2 = 0.019$). Thus there is no evidence that the particular type of object-pair affected participant's performance.

2.2.3. Discussion

Participants were required to generalise novel noun-noun compounds to either an object-pair which consisted of identical constituent objects as the original referent but combined via a different relation or to an object-pair combined via the same relation as the original referent but with different colour versions of the constituent objects (correct generalisation). It was found that the ability to make generalisations on the basis of relational identity improved with age, with 4-year-olds being the youngest group that chose the correct object-pair at above chance level. They are therefore the youngest group that appear to have understood that relational information is a crucial part of a compound's meaning and perceptual features of the object-pair are irrelevant or at least less important. Importantly, 2-year-olds and 3-year-olds made correct selections less often than would be expected by chance, even though significantly so only for 2-year-olds. This suggests that rather than generalising on the basis of relational information, they were generalising on the basis of perceptual identity of constituent objects, i.e. non-relational perceptual information. Overall, we therefore have evidence for a developmental focus shift from generalising on the basis of non-relational aspects towards relational aspects of the referents. Importantly, children were not simply becoming better at understanding and generalising noun-noun compounds; there was a qualitative difference in performance between 2-year-olds and 4- and 5-year-olds as they based generalisations on different aspects of the compound referents presented to them.

Whether a compound referent was combined via a HAS or FOR relation had no effect on the performance of any of the age groups. We therefore found no evidence for a focus shift from static information (as in HAS relations) to dynamic information (as in FOR relations). Additionally, performance was not found to be better with certain object-pairs compared to others, meaning that our results should be generalisable to other objects.

The finding that 2-year-old children and 3-year-old children did not choose on the basis of relational identity might mean that they did not consider relational information as part of the compound meaning. However, the question arises whether the information processing demand might have been too high for these young children in our experiment so that they were not able to remember the relations. To rule out such an explanation, we conducted a control study with 2-year-old children in which they experienced an identical procedure to that of Experiment 1 with the exception that they were tested on their memory for the relation between the objects instead of being asked to generalise the compound to a novel exemplar. If participants were able to identify the previously seen relation then their performance in Experiment 1 was truly a result of not understanding the relational information as part of the compounds meaning. In other words, this experiment allowed us to determine whether the performance of the younger children was due to a true linguistic problem.

2.3. Experiment 2

2.3.1. Method

2.4.1.1. Participants. Participants were twelve 2-year-olds (mean age 32.4 months, *SD* = 2.1). Children were recruited from the same region as those in the previous experiments and the process of obtaining consent was the same. All participants were native speakers of English.

2.3.1.2. Materials. Materials used were identical to those in Experiment 1 i.e. the same type and version of objects / object-pairs were used at the same points in the procedure.

2.3.1.3. Procedure. The procedure was identical to that of Experiment 1 with the exception that in Part 3 (test) when participants were required to pick between the two object-pairs, they were asked "Now how did these toys go together yesterday, was it like this or like that?" instead of being asked to find a referent for the compound-noun they had learned the day before.

2.3.2. Results

The mean number of correct selections (selection of the object-pair which shared its relation with the one seen the previous day) across participants was 4.7 out of 6 (*SD* = 1.0).

Comparing the number of correct selections against chance (3 out of 6) showed that participants chose the correct object-pair significantly more often than would be predicted by chance, $t(11) = 5.9$, $p < .001$. Separating out trials on the bases of relation type of the original referent showed that mean number of correct selections was 2.5 out of 3 ($SD = 0.7$) for FOR relation trials and 2.2 out of 3 ($SD = 0.7$) for HAS relation trials. A t-test found no significant difference in performance between the two relation types, $t(11) = 1.2$, $p = .266$.

2.3.3. Discussion

In Experiment 2 we investigated whether 2-year-old children can remember which relation of a particular object-pair they had previously seen when presented with exactly the same processing demands as in Experiment 1. Two-year-olds were able to pick out the object-pair that shared its relation with the object-pair they had seen the day before, and their performance for the two relation types (HAS versus FOR) did not differ. These findings therefore rule out the possibility that 2-year-old's, and by extension 3-year-old's, performance in the previous experiments was a result of them being overloaded with information and/or of simply not being able to remember how the constituent objects in the training object-pairs were related. These findings therefore support the suggestion that the younger children in Experiment 1 did not consider the relation an important part of a compound's meaning.

Note that the first part of the experiment, i.e. the presentation of the constituent objects and the compound, was the same in Experiments 1 and 2. Therefore, the information encoding demand was the same in the two experiments, and children might have been equally distracted from the relational information during the training phase in both experiments. Also note that the memory demand during the test phase was the same in the two experiments. Even though only in Experiment 1 compound names played a role during the test phase, participants did not actually need to know the names for the objects or the object pairs to answer correctly.

They only needed to have understood that the relation between constituent objects is part of a compound's meaning, irrespective of the compound's exact name.

An alternative explanation of Experiment 1, namely that 2-year-olds did not consider the relation to be part of the compounds' meaning, could be that the 2-year-olds and to some extent 3-year-olds may have simply considered perceptual identity of constituent objects to be a more important part of a compound's meaning than relational information. Research on children's novel noun interpretations has found that 2- and 3-year-olds can generalise names of novel objects on the basis of factors other than perceptual features under the right circumstances (e.g. on the basis function as in for instance Kemler Nelson, 1999; Kemler Nelson, Russel, Duke, & Jones, 2000). Therefore, a further control experiment was carried out in which children's ability to generalise compounds on the basis of their relational components was investigated in the absence of competing perceptual features of the objects.

2.4. Experiment 3

In Experiment 3, children were asked to extend compounds to one of two exemplars that differed in terms of relational information, but both had identical component objects to the training object-pair. For instance, both were pairs of a purple *kig* and an orange *donka*, but they differed in terms of the relation (HAS vs. FOR). We tested 2- and 3-year-old children because these two age groups did not generalise compounds on the basis of relational identity in Experiment 1. Five-year-olds were included as a comparison group because they had revealed a focus on relational information in Experiment 1.

The procedure of Experiment 3 was the same as that of Experiment 1 with the exception that in the test phase of the experiment, participants were now required to pick between two object-pairs that both had perceptually identical constituent objects as the original referent, but only one of them had the same relation as the original referent. This made the latter the correct choice.

If the performance of 2- and/or 3-year-olds improved significantly to a level above chance in this experiment, then this would suggest that their performance in Experiment 1 was the result of them considering the non-relational perceptual identity to be a more important part of a compound's meaning.

This experiment also further explored the findings of Experiment 1 that the type of the relation (HAS or FOR) did not make a difference for the performance of any age group, therefore failing to provide evidence for a developmental shift from static to dynamic information. Relation type may matter now that perceptual features are held constant.

2.4.1. Method

2.4.1.1. Participants. Participants were 15 two-year-olds (mean age 31 months, *SD*=2.5, 8 males), 16 three-year-olds (mean age 40 months, *SD*=3.5, 7 males) and 25 five-year-olds (mean age 66 months, *SD*=2.9, 10 males). Children were recruited from the same region as those in Experiment 1 and the process of obtaining consent was the same. All participants were monolingual and native speakers of English.

2.4.1.2. Materials. Objects and object-pairs were identical to those of Experiment 1, but only one colour version of each object was used to create the object-pairs.

2.4.1.3. Procedure. The procedure was identical to that of Experiment 1, except for the options that were presented for the test phase (Part 3). Participants were asked to pick between two object-pairs, of which one was identical to the one used to introduce the compound and the other consisted of the identical constituent objects as the original referent, but the objects were combined using a different relation (HAS instead of FOR or vice versa).

For example Panel C and Panels E of Figure 2.1 display the two object-pairs participants could choose between in Part 3 of the procedure.

2.4.2. Results

Selection of the matching i.e. previously seen object-pair was considered a correct response. Figure 2.3 displays the results. The number of correct selections was analysed with a split-plot ANOVA with Age group as a between participants factor and Relation type as a within participants factor. The test indicated a significant main effect of Age group (F(2,53) = 22.5, p < .001, partial η^2 = .460) with the correct selection of the matching object-pair increasing with age. Tukey HSD post-hoc tests revealed that selection of the correct object-pair differed significantly only between 2 and 5-year-olds, and 3 and 5-year-olds (2 versus 5: p < .001, 3 versus 5: p < .001). There was no significant effect of Relation type (F(1,53) = 0.4,

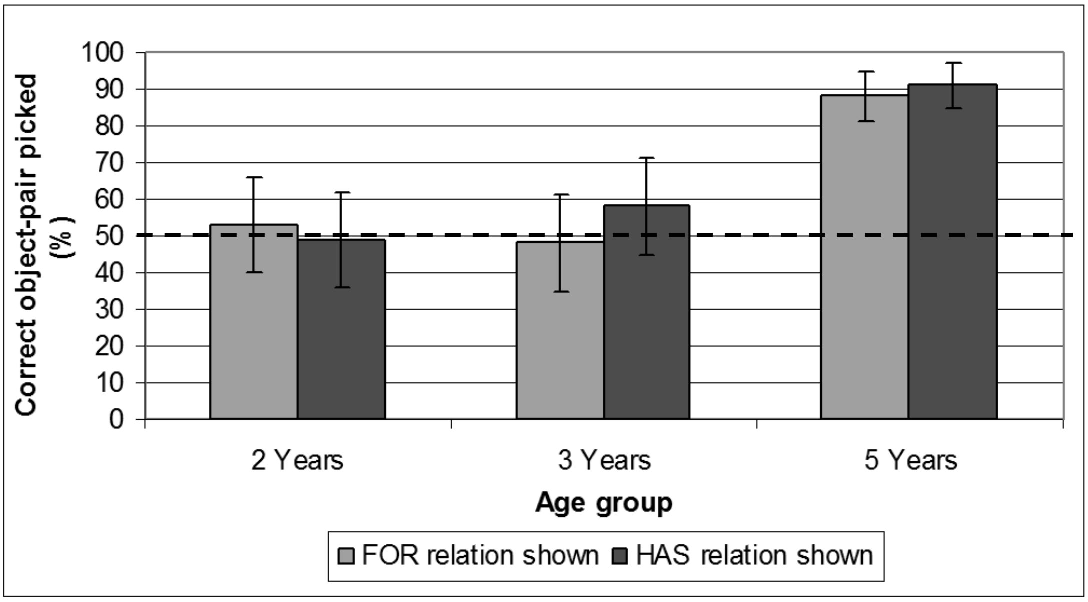


Figure 2.3. Experiment 3: The effect of age group and relation type on participants' ability to correctly extend a novel compound-noun used to label a novel object-pair by picking the one which shares its relation on the following day (50% line marks chance level). Error bars represent standard error.

$p = .531$, partial $\eta^2 = .007$), suggesting that selection of the correct object-pair was not more likely for one relation type than the other. The interaction between Age group and Relation type was not significant either ($F(1,53) = 0.8$, $p = .468$, partial $\eta^2 = .028$).

Additionally number of correct selections was compared against chance (3 out of 6 responses): 2-year-olds: $t(14) = 0.2$, $p = .836$; 3-year-olds: $t(15) = 0.5$, $p = .606$; and 5-year-olds: $t(24) = 10.6$, $p < .001$. This indicated that only the 5-year-olds selected the correct object-pair at above chance level.

A repeated measures ANOVA was conducted to investigate the effect of the Object-pair type (coodle tez vs. kig donka vs. koba sav vs. rinta dax vs. tidgy mov vs. wug binto) on participant's performance. The test indicated no significant effect of Object-pair type ($F(5, 275) = 0.5$, $p = .792$, partial $\eta^2 = .008$). Thus there was no evidence that the particular type of object-pair shown to the participant affected their performance.

2.4.3 Discussion

In Experiment 3 we investigated the ability of children to generalise compounds on the basis of the relational components of compounds' meaning in the absence of competing perceptual features. As in the Experiment 1, 5-year-olds out-performed 2- and 3-year-olds, confirming a developmental focus shift towards relational information.

Two- and three-year-olds did not select the matching object-pair more often than would be expected by chance. They therefore did not focus on the relational information as part of the compounds' meaning, and their failure in Experiment 1 was not due to them considering it a less important part of the compound's meaning than perceptual identity of constituent objects.

Replicating the results of Experiment 1, 5-year-olds did choose the relational match more often than would be expected by chance and therefore were using relational information to guide their choices. Again similarly to Experiment 1 the relation type (HAS versus FOR) had no effect on whether the correct object-pair was selected for any of the age groups tested. Thus again, we found no evidence for a focus shift from static to dynamic information. Furthermore and in support of results of Experiment 1, the particular object-pair shown to participants did not affect their choices.

We have therefore ruled out an alternative explanation for the results of Experiment 1, namely that younger children considered perceptual identity of constituent objects to be a more important part of a compound's meaning than relational information.

2.5. General Discussion

In this study we addressed the question whether the dynamic nature of word referents and/or the relational nature of word referents poses a challenge during early word learning. For that, we investigated a developmental focus shift from non-relational to relational aspects of word referents and from static to dynamic aspects during initial interpretations of novel compound words. We tested whether 2- to 5-year-old children as well as adults generalised novel compounds on the basis of their relational components, with relational components being either static (HAS relation) or dynamic (FOR relation).

In Experiment 1 we found that 2-year-olds' generalisations were based on perceptual identity of constituent objects. This changed to generalisations based on relational identity during the development between age 2 and 5 years, with 4-year-olds being the youngest group that significantly based their generalisations on relational information. As opposed to simply becoming better at understanding noun-noun compound with age, children showed a qualitative difference in terms of the aspects of the compounds' referents that they choose to base their generalisations on. Children's focus shifted from non-relational towards relational aspects of compound referents and therefore underwent a developmental focus shift from non-relational to relational aspects of compound referents. We therefore have evidence that young children find it challenging to link novel compounds to relational information instead of non-relational perceptual information.

Follow-up control experiments ruled out some alternative explanations for these results. Experiment 2 demonstrated that 2-year-old and by extension 3-year-old children, despite their failure to generalise compounds on the basis of relational information in Experiment 1, were able to remember how the constituents of the object-pairs related to each other. Experiment 3 ruled out that 2- and 3-year-olds failed to generalise a novel compound on the basis of relational information because they considered it a less important part of the compounds' meaning than the perceptual identity of the constituent objects.

It could be argued that the correct choice in the example presented in Figure 2.1 (panel D), while sharing the same function as the object-pair seen the previous day (panel C), also looks more similar in terms of overall shape than the alternative choice (panel E). Therefore, children might be responding to the overall shape instead of the relation between the constituent objects. However, as the shape-bias literature discussed in the introduction indicates, the strongest tendency for using shape similarity as a basis for extension should be visible for the youngest children. In contrast, the youngest group in Experiment 1, namely the 2-year-olds, overwhelmingly chose the colour rather than the function match. And maybe more importantly, participants could only base their choice on overall shape in the case of compounds with HAS relations, not FOR relations. The latter relations are presented in a dynamic way (as indicated in panels E-G of Figure 1). Therefore there is no stable overall shape of the object pair. And given that we did not find any differences between responses to

HAS and FOR compounds, we can rule out that any participant group based their responses on the overall shape of the object pairs.

We also found that the type of relation (HAS or FOR) that the objects were combined with had no effect on performance for any of the age groups tested. Thus, the static or dynamic nature of the relation had no effect on whether children based their generalisations on it. Therefore our data does not support a developmental shift in focus from static to dynamic aspects of the compounds' referents. This result might be somewhat surprising given the bias towards HAS relations in 2- and 3-year-olds' interpretations of novel compounds (e.g. *kig donka*) suggested by Krott et al. (2010). However, a closer look at Krott et al.'s (2010) study shows that children were able to show a HAS bias without actually understanding that the relation is part of the compounds' meaning. Children were not asked to generalise compounds, but to find the best referent for a novel compound (e.g. *kig donka*). Younger children might have been drawn to the HAS relation referent because of other reasons, e.g. because they found HAS combinations more interesting. This means that a generalisation task such as the one used in the present study is a better tool for testing children's actual understanding of what novel words mean / refer to.

In sum, our study showed that, when children were asked to extend a novel compounds, they shifted their basis for their interpretation from non-relational (i.e. perceptual) to relational aspects of the original referent during development, but the static or dynamic nature of the relation had no effect on their generalisations. This suggests that young children struggle with the relational component of compound meanings. Once the relational component does not present a problem anymore, it does not matter whether the relational component is dynamic or static.

Verbs versus nouns

As mentioned in the introduction, it has been found that nouns are typically acquired earlier than verbs (e.g., Genter, 1982; for a recent review see Waxman et al., 2013). Because nouns in the child vocabulary typically refer to objects, while verbs to actions, our finding can add to the debate why verbs might be acquired later. We have found that relating a word to a relation is difficult for young children because it is a relation, not because the relation might be visible to the child as a dynamic event. In other words, the dynamic nature of the referent does not seem to be problematic. If we generalise our conclusions, then one reason for verbs being more difficult to acquire than nouns might be because they refer to relations, but not because they refer to dynamic events. Further research is needed to confirm this generalisation.

Our finding that younger children tend to focus on perceptual identity of constituent objects rather than relational information resembles the finding in verb learning studies that younger children tend to focus too much on agents and objects involved in a scene when trying to interpret novel verbs (Behrend, 1990; Forbes & Farrar 1993; Imai et al., 2005; Imai et al., 2008; Kersten & Smith 2002). This, coupled with our finding that the type of relation had no effect on whether children based their generalisations on it, suggests that a non-relational to relation focus shift rather than a static to dynamic shift might occur in verb learning as well. In other words, children's focus might be shifting towards the action because it is relational, rather than because it is dynamic or a motion aspect of the scene.

It should be noted that young children can and do perceive relational information. There is plenty of evidence that even infants are sensitive to the conceptual components present in dynamic action scenes, i.e. scenes that they would need to process in order to acquire verbs and other relational terms (Pruden et al, 2012; Goksun, Hirsh-Pasek, &

Golinkoff, 2010; Pruden, Hirsh-Pasek, & Goliknoff, 2008; Golinkoff & Hirsh-Pasek, 2008; Waxman et al., 2009; Arunachalam & Waxman, 2011). Similarly, in Experiment 2 of our study two-year-olds had not only perceived the relation between the constituent objects of the object-pairs, but they were also able to recall it the following day. This makes it even more striking that young children do not easily map novel words onto relational information when they are asked to extend them to new instances, as seen in the present study and in verb extension studies (Behrend, 1990; Forbes & Farrar 1993; Imai et al., 2005; Imai et al., 2008; Kersten & Smith 2002). Therefore, while younger children may possess the prerequisite conceptual components to acquire and extend words referring to relational information, it appears to be mapping the verb to the relational part of the scene that they struggle with. In terms of Gentner & Boroditsky's (2001) requirements for learning relational terms, it appears that younger children are not struggling to make sense of events, but are rather struggling to map words onto the appropriate components of the event.

We are not arguing that the relational / non-relational nature of referents is the only important factor during early verb and noun learning. See, for instance, Golinkoff & Hirsh-Pasek (2008) for a variety of reasons why verbs are more difficult to acquire than nouns. They highlight the factors we have focused on in the current paper, i.e. that children may have difficulty extracting the relevant components from dynamic events and categorising them and that they may also have problems mapping verbs due to their inherently relational nature. In addition, they suggest that children's early preference for relying on perceptual cues may be enough to successfully map nouns, but not verbs. Furthermore, young children may not be sensitive to other cues which benefit verb mapping until later, such as linguistic cues or the social intent of the speaker.

There is also evidence for the importance of language-specific linguistic factors for verb and noun acquisition (e.g. Imai et al., 2008; Tardif, 1996; Tardif, Gelman, & Xu, 1999, Tardif, Shatz, & Naigles, 1997). Is has been pointed out that the noun advantage over verbs is characteristic of ‘noun-friendly’ languages like English, Dutch, or German. In contrast, in ‘verb-friendly’ languages like Mandarin, Japanese, or Korean, verbs have a special position. In those languages, verbs often occur without noun arguments if the latter can be inferred from the context. This attenuates the noun advantage in a language or can even delete it. The conceptual disadvantage of a word class that refers to a relation can therefore be qualified by the way it appears in the language input.

In addition, recent research by McDonough et al. (2011) suggests that nouns are not acquired before verbs because of their particular form class, but that it is the imagability of words which determines how early they are acquired i.e. how perceivable, concrete and easy to individuate they are. They found that words rated high in imagability were acquired earlier than those with low imagability. In fact imagability was found to be a stronger predictor of age of acquisition than form class. McDonough and colleagues suggest that nouns may tend to be acquired earlier than verbs because they tend to be higher in imagability. However, imageability and form class together were found to account for only 22% of the variance of age of acquisition in their sample. This suggests that other factors are involved as well. We suggest that one such factor may be the degree of relational nature of the word.

Relational shift in noun acquisition

The finding that children focus initially on non-relational features of objects / scenes when identifying the referent of a novel word and slowly during development learn to focus on relational information is not restricted to compound noun and verb learning. This developmental shift can also be seen in the acquisition of morphologically simple nouns such as *ball* or *cup*.

We have mentioned that concrete nouns usually have two semantic dimensions, the perceptual features of the referent objects and the functions of the referent objects, with the former being static and non-relational and the latter being dynamic and relational. Young children have been found to have a bias to attend to the static perceptual features rather than the dynamic function when initially interpreting a novel noun. This is evident in the 'shape bias', which refers to the finding that when young children are asked to extend a novel noun, they tend to do so on the basis of the shape of the objects, i.e. perceptual features, instead of the function. Importantly, this behaviour stands in contrast to what adults usually do because, as mentioned, for adults the name of an object is primarily based on its function (e.g. Miller & Johnson-Laird, 1976).

The shape bias was demonstrated, for instance, by Gentner (1978). She pitted perceptual (thus non-relational) features against function in a task where participants were shown two novel objects that differed in both form and function, and heard novel names for each of the objects. Participants were then presented with a hybrid object that possessed the form of one of the objects and the function of the other, and asked to name it. The youngest children in the study (aged 2½ to 5-years) named this hybrid object on the basis of form rather than function, while there was an increasing focus on function by older children. Such a developmental trajectory was also found by Merriman, Scott, and Marazita (1993) who asked children aged 3;8, 4;8, and 6;1, to generalise a novel name given to a novel object to either an object that resembled the training object perceptually or one that resembled it in function. They found that the tendency to select the functionally similar object increased with age. The importance of perceptual features for young children is also evident in a study by Smith, et al.

(1996) who found that 3-year-olds' but not adults' generalisations of novel names for novel objects were influenced by the relative saliency of perceptual features and not by functional information. And even when an object's function is emphasised during word learning, 3- and 5-year-olds might still generalise its name on the basis of shape rather than function (Graham, Williams, & Huber, 1999).

It should be noted here that even two-year-olds can extend a novel noun on the basis of features other than shape, such as function or conceptual information if the circumstances are right; if for instance the children experience the function for themselves or if they are presented with conceptual information about the objects (e.g., Booth, Waxman, & Huang, 2005; Booth & Waxman, 2002; Kemler Nelson, 1999; Kemler Nelson, Russell, Duke, & Jones, 2000). But when young children are given minimal exposure and experience with an object they generally tend to focus on the shape rather than the function (Kemler-Nelson, 1999). This means that there appears to be an initial attention bias to the shape rather than the function (Smith, Jones, & Landau, 1996).

The conclusion that it is difficult for young children to acquire relational aspects of word meanings could be extended to the phenomenon of the shape bias. The developmental shift from shape to function might also reflect a focus shift from non-relational to relational aspects rather than a focus shift from static to dynamic aspects. That would mean that children are truly shifting their focus towards the object's function as opposed to the aspect of motion. Note that we are arguing for a developmental shift in initial focus when understanding novel nouns and when no additional support for the focus is provided (e.g. when children have not experienced the function for themselves). We do not claim that young children are unable to consider function (or other conceptual information) as a basis for noun meaning. Under the right circumstances young children can indeed generalise names of novel objects on the basis of function (e.g. Kemler Nelson, 1999; Kemler Nelson, Russel, Duke, & Jones, 2000).

Last but not least, the shift from non-relational to relational understanding in word learning is evident in another sub-type of nouns, namely relational nouns (e.g. *sister* or *enemy*). Those have been found to be initially interpreted as referring to objects, while an understanding that they refer to relations emerges later during development (Gentner & Boroditsky, 2001).

Relational aspects in familiar words

Our and previous findings stand in contrast to the fact that children do use compounds, verbs, and relational nouns correctly in their speech from quite early on. For instance, Golinkoff et al. (2002) reported that 3-year-olds have acquired the semantic ‘essence’ of familiar motion verbs, being able to identify verbs like ‘dancing’ from point-light displays that only preserve the semantic components of verbs such as manner and path, but abstract from non-essential information such a particular agent performing the action. Studies such as ours, testing children on their interpretation of novel words, therefore tap into children’s initial interpretations of unfamiliar words, which are corrected with more experience.

What drives the relational shift?

Why do young children focus on static aspects such as objects and perceptual features rather than relations between objects when trying to understand what a novel word refers to, and what drives a developmental shift from non-relational to relational properties of word referents? We suggest that an initial bias towards static aspects might be caused by perceptual salience as an attentional cue that children use when making sense of unfamiliar words. This cue is especially important early on in language development and is replaced by other strategies later during development (for a similar account, see the Emergentist Coalition Model as presented in, e.g., Hollich et al., 2000).

What drives the developmental shift from non-relational to relational properties might be the experience with the word class. As has been pointed out before for verbs (e.g., Imai et al., 2008; Golinkoff et al., 2002), children need to learn the semantic criteria for generalisation of a word by discovering the invariants across exemplars. But because initial word interpretations are based on one or two exemplars, discovering the invariants is difficult. One factor that might play a role here is the experience with the word class. In case of compound words, enough experience can lead to the discovery that a compound refers to a class of object combinations that is defined by the relation between the constituents of object-pairs and not by the perceptual features of the objects. This insight might first be present for individual compounds and with enough experience becomes part of the knowledge about compounds as a category. Similarly, generalisation over various verbs can guide the interpretation of a novel verb by shifting the focus onto the action of a scene. Such insights need experience and that is what younger children have less of compared to older children and adults. Thus, older children and adults might use a top-down approach, narrowing their search for invariants on the basis of their knowledge about the word category, while younger children might follow rather a bottom-up approach that is affected by perceptual salience of the potential word referents in a scene.

Compound acquisition

With regards to the acquisition of compound words, our study supports previous evidence that an adult-like understanding of the relational component of compounds is acquired slowly (e.g., Nicoladis, 2003; Krott et al., 2009; 2010). Our findings clearly show that 2- and 3-year-old children do not have a full understanding of the importance of compound relations. This was most evident in Experiment 3, where 2- and 3-year-olds could not select the correct compound referent despite the fact that the correct referent was identical to the original referent. They clearly did not understand the relation as a very important part of the compound's meaning, even though children at this age can recognise the relations in a memory task, as shown in Experiment 2. Thus, 2- and 3-year-olds do not seem to understand that the relation is actually part of a novel compound's meaning, at least when initially exposed to the compound.

In conclusion, through the use of noun-noun compounds we were able to investigate whether relational aspects or dynamic aspects of word referents are challenging in early word learning. We found that, during their development, children shifted their basis for compound-noun extension from non-relational (i.e. perceptual) to relational aspects of the original referent. The static or dynamic nature of the relation had no effect on children's generalisations in any age group. Therefore our findings suggest that young children might struggle with relating novel words to relations. In contrast, we have found no evidence that dynamic aspects of word referents are more challenging than static aspects of word referents. In other words, children's shift into a more adult-like way of interpreting the meaning of novel words might not be driven by an increased focus on motion, but rather by an increased focus on how thing are related to each other.

CHAPTER THREE

THE BENEFIT OF MAKING RELATIONS EXPLICIT IN NOUN-NOUN COMPOUND LEARNING

Abstract

Children's understanding of noun-noun compounds (e.g. *chocolate cake*) is still under development during the pre-school years. In particular they seem to have difficulty understanding that the relational component of compound-noun meaning is a crucial part of the compound's meaning. The current study aims to investigate whether making the relation explicit when the compound is first encountered will lower the age at which children reliably encode it as part of the compound's meaning. This was achieved by asking children between the ages of 2- and 5-years to extend novel noun-noun compounds (e.g. *koba sav*), used to label pairs of novel objects combined via either a HAS or FOR relation. Participants could extend a compound incorrectly to an object-pair consisting of the same constituent objects as the original exemplar, but combined via a different relation, or correctly to an object-pair consisting of the same constituent objects as the original exemplar and combined via the same relation. In the first experiment the relational component was not made explicit. In the second experiment it was. Results show that making the relation explicit helped to reduce the age at which children reliably made correct extensions. Therefore highlighting the relational component of compound-noun meaning at encoding appears to have the effect of keying younger children into the importance of it in defining the compound.

3.1. Introduction

In English, nouns play a central role within children's early vocabularies (Gentner, 1982). They start off with morphologically simple nouns such as *cat*, *spoon*, *chair*, but quickly also produce noun-noun compounds (e.g. *toy-box*, *hairbrush*, *pork-pie*), i.e. possibly before their second birthday (e.g. Clark, 1981; 1983). There is even evidence for the coinage of novel compounds at the age of two (e.g. Clark, 1981).

The meaning of a noun-noun compound is defined not only by the meaning of the constituents (e.g. the meaning of the nouns *box* and *toy*, in the *toy-box* example; or *pie* and *pork* in the *pork-pie* example) but also by how the constituents are related. For instance, a *toy-box* is a *box* FOR storing *toys*, and not for example a *box* that HAS a *toy* attached to the side of it; a *pork-pie* is a *pie* that HAS *pork* in it, and not for example a *pie* FOR eating with *pork*.

The FOR and HAS relations illustrated in the above examples are but two of a variety of possible relations via which the constituents of a noun-noun compound can be related. See Gleitman & Gleitman, (1970); Downing, (1977); Bauer, (1983); for the most commonly used relations. As stated, the relation that exists between the constituents of a noun-noun compound is a crucial part of the compound's meaning. The noun-noun compound *toy-box* can refer to any type of box used for storing any type of toy. It is not the precise identity of the constituents which is important for compound meaning, only the way in which they are combined i.e. via a FOR relation in the case of a *toy-box*.

In addition to their ability to produce noun-noun compounds from early on, children have also been shown to understand the structure of noun-noun compounds, i.e. the role of each noun as modifier and head from 2-years of age (Clark, Gelman & Lane, 1985). The same study also found that children of the same age demonstrated understanding that sub-categories related by inherent (e.g. *pencil-house* for a house made out of pencils) and semi-inherent (e.g.

snake-block for a block with a snake painted on it) categories are more appropriate candidates for labelling with compounds than those related by accidental properties (e.g. *cat-chair* for a chair with a cat sitting on it).

However children's understanding of noun-noun compounds is not complete at this age. In particular their understanding of the relational component of noun-noun compounds is still under development during the pre-school years. Nicoladis (2003) found that even between 3- and 4-years of age there is a significant improvement in children's understanding that noun-noun compounds generally refer to two interacting objects, as opposed to two objects that just happen to be next to each other. Furthermore, errors interpreting noun-noun compounds as two objects located next to each other can even occur in 6-9-year-olds (Parault, Schwanenflugel, & Haverback, 2005).

Further research by Krott, Gagné & Nicoladis (2009) and Krott, Gagné & Nicoladis (2010) found that young children display a HAS/LOCATED bias when trying to determine the meaning of novel noun-noun compounds when compared to older children and adults. That is, 4- and 5-year-olds tend to explain novel compounds made up of familiar nouns using HAS/LOCATED relations rather than FOR relations (Krott et al., 2009) and 2- and 3-year olds tend to interpret novel noun-noun compounds (e.g. *wug binto*) as having a HAS/LOCATED relation rather than a FOR relation (Krott et al, 2010).

In addition, children's understanding that it is the relation that exists between the constituents of a noun-noun compound, and not the perceptual identity of those constituents that defines the compound, develops gradually during the pre-school years (see Chapter 2 of current thesis). When required to extend a novel noun-noun compound (e.g. *coodle tez*) on the basis of either shared identity of constituent objects or shared relation between constituents (e.g. a HAS relation), 2-year-olds extended overwhelmingly on the basis of object identity.

This tendency shifted with age to extensions based on a shared relation, with 4-year-olds being the youngest age-group to do this relatively consistently. These results suggest a relational shift in focus from perceptual features toward relational features for noun-noun compound extension during the pre-school years. Children are not simply getting better with age, they are changing what they choose to base their extensions on.

The latter findings (Chapter 2) represent children's ability to make use of the relational component of compound-noun meaning to make correct extensions, without any additional information. The question arises whether explicitly drawing children's attention to the relation at encoding will allow them to make use of this component in order to make correct extensions. The 'shape bias' literature in simple noun extensions suggests that this may be the case. For adults, the name of an object is based on the function of the object, not on its shape (e.g. Miller & Johnson-Laird, 1976). That is, a pen is called a pen because you can write with it independent of whether it looks like a prototypical pen or, for instance, a banana or a mouse. This shape bias refers to the finding that when required to extend novel nouns (e.g. *dax* or *kig*) on the basis of either shape or function, younger children did so on the basis of shape, while older children did so on the basis of function (Gentner, 1978; Merriman, Scott, and Marazita, 1993; Smith et al., 1996; Graham, Williams, & Huber, 1999). However, when function is made explicit to children, either through demonstration or by allowing them to experience the function for themselves, even two-year-olds are able to extend nouns on the basis of function (Kemler Nelson, 1995; Kemler Nelson, 1999; Kemler Nelson, Russel, Duke, & Jones, 2000; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Diesendruck, Markson, & Bloom, 2003).

In the current study, we thus investigated whether explicitly drawing children's attention to the relational component of noun-noun compound meaning would allow younger children to use this information to base their extensions on it. We compared young children's extensions of novel noun-noun compounds when the relational component was highlighted by the experimenter during first exposure vs. when it was not. The relational component was highlighted by the experimenter verbally drawing participants' attention to it (e.g. stating that one component HAS another; this is a *donka* that HAS a *kig*). The relational component could consist of a HAS relation or a FOR relation. A HAS relation involved one object having another permanently attached to it. A FOR relation involved one object being used for another one, e.g. for storing the other object. Previous results on compound-noun extensions predicted that 2- and 3-year-olds should not be able to extend compound nouns on the basis of the relational component when the relation is not highlighted, while 5-year-olds should. Based on the finding that highlighting function helps young children to extend simple nouns on the basis of function, we expected that explaining the relation would also allow younger children to base their extensions on the relational component. In addition these previous findings suggest that the nature of the relation (HAS or FOR) should not affect children's tendency to base their extensions on it. We tested these hypotheses in two experiments. Experiment 1 is very similar to Experiment 3 of Chapter 2 in that it did not provide any verbal explanations of the relations (the only difference being that in the current study all parts of the procedure took part on a single day), while in Experiment 2 of the current chapter we verbally highlighted the relation.

3.2. Experiment 1

3.2.1. Method

3.2.1.1. Participants. Participants were 20 two-year-olds (mean age 30 months, *SD*=3.6, 7 males), 23 three-year-olds (mean age 40 months, *SD*=2.8, 14 males) and 19 five-year-olds (mean age 63 months, *SD*=3.5, 8 males). Participants were recruited from nurseries and schools located in the West Midlands area of the United Kingdom. Permission for children to participate was granted by either the owner of the nursery or head teacher of the school. Parental consent was obtained when requested by the nursery owner / head teacher. All participants were native speakers of English, and for the majority this was their only language. The exceptions were two 3-year-olds and one 5-year-olds who spoke an additional language, although all spoke fluent English. There was no indication that participants who spoke another language performed any differently from those of the same age who spoke only English. We therefore included these children in our analysis.

3.2.1.2. Design. This experiment used a mixed experimental design that investigated the effect of the independent variables Age group (2, 3, and 5-year-olds) and Relation type (HAS vs. FOR) on the dependant variable correct extensions of novel compounds.

3.2.1.3. Materials. The same novel objects as used in Chapter 2 were used and given the same novel names. A pen, pencil, spoon, and teddy bear were again used as distracters in Part 1 of the procedure. The novel objects were grouped in the same way as Chapter 2 to make novel object-pairs (e.g. a *Kig* and a *Donka* were grouped to make a *Kig Donka*). As in Experiment 3 of Chapter 2, only one colour version of each object was used to make the object-pairs. As in Chapter2, the constituent objects were combined via either a HAS relation (e.g. where one object was permanently attached to the other) or a FOR relation (e.g. where one objects was used for storing the other).

3.2.1.4. Procedure. Participants were tested individually in a quiet area of their nursery or school. All parts of the procedure took place on the same day. During Part one of the procedure, participants were taught the names of the individual objects which would make up the object-pairs in Part two. In Part two of the procedure participants were introduced to

Part 1 – training of object labels	 A) “This is a kig, and this is a kig”  B) “This is a donka, and this is a donka”
Part 2 – training of compound labels	 C) Exp1: “This is a kig donka” Exp 2: “This is a donka that has a kig, so it’s a kig donka”
Part 3 – testing compound understanding	 D) HAS relation (same relation)  E) FOR relation (different relation) “Can you show me a kig donka?”

Figure 3.1. Experiment 1 & 2 procedure example. Extension of the compound-noun to Panel D would represent extension to an object-pair which shares relation type with the original referent. Extension of the compound-noun to Panel E would represent extension to an object-pair which does not share the same relation type. Note that Panel C demonstrates the difference between Exp 1 and 2, namely that the relation between the constituent objects is verbally highlighted in Exp 2.

the object-pairs and told the novel noun-noun compound for the object-pair. In part three of the procedure, participants were asked to extend the novel noun-noun compound to one of two object-pairs. The first object-pair was identical to the one shown to them in Part two of the procedure, i.e. it consisted of the same objects as the original referent and the objects were combined via the same relation (e.g. a HAS relation). This would be the correct selection, i.e. the selection expected by adults. The second object-pair consisted of the same objects as the exemplar shown to them but the objects were combined via a different relation (e.g. a FOR relation). All parts of the procedure were identical to those of Experiment 3 in Chapter 2. The exception being that Part three took place immediately following Part two in the current experiment, not the following day. See Figure 3.1. for an example of the procedure.

3.2.2. Results

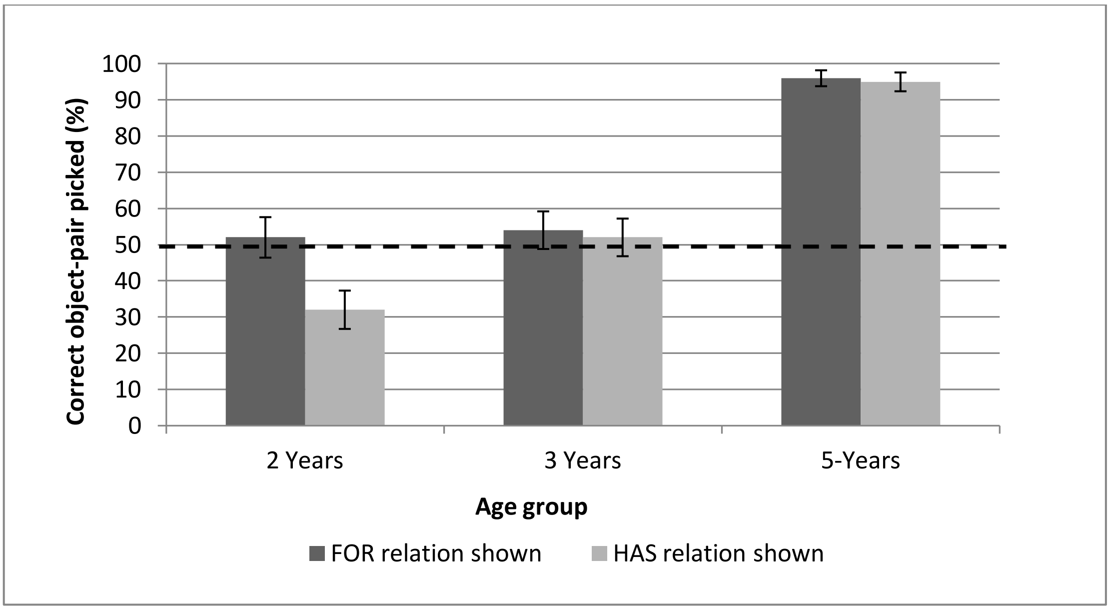


Figure 3.2. Experiment 1: The effect of age group and relation type on object-pair picked (50% line marks chance level, error bars represent standard error).

Selection of the matching i.e. previously seen object-pair was considered a correct response. Figure 3.2 displays the results. The number of correct selections was analysed with a split-plot ANOVA with Age group as a between participants factor and Relation type as a within participants factor. The test indicated a significant main effect of Age group ($F(2,59) = 67.2$, $p < .001$, partial $\eta^2 = .695$) with the correct selection increasing with age. Tukey HSD post-hoc tests revealed that selection of the matching object-pair differed significantly between 2- and 5-year-olds, and 3- and 5-year-olds (2 versus 5: $p < .001$, 3 versus 5: $p < .001$), but not between 2- and 3-year-olds (p = .051). There was no significant effect of Relation type ($F(1,59) = 1.9$, $p = .169$, partial $\eta^2 = .032$) or any significant interaction between Age group and Relation type ($F(2,59) = 1.2$, $p = .305$, partial $\eta^2 = .039$), suggesting that selection of the matching object-pair was not more likely for one relation type than the other, and this was the same across the age groups.

Additionally, we conducted planned comparisons of the number of correct selections against chance (3 out of 6 responses): Only the 5-year-olds selected the matching object-pair at above chance level (5-year-olds: $t(18) = 26.4$, $p < .001$; 2-year-olds: $t(19) = -1.9$, $p = .076$; 3-year-olds: $t(22) = 0.9$, $p = .383$).

A repeated measures ANOVA was conducted to investigate the effect of the Object-pair type (coodle tez vs. kig donka vs. koba sav vs. rinta dax vs. tidgy mov vs. wug binto) on participant’s performance. The test indicated no significant effect of Object-pair type ($F(5, 305) = 1.1$, $p = .363$, partial $\eta^2 = .018$). Thus there is no evidence that the particular object-pair shown to the participant affected their performance.

3.2.3. Discussion

Participants were required to extend a novel noun-noun compound from an exemplar object-pair to either of two object-pairs: a) a matching object-pair (correct response), i.e. an object-pair that had the same constituent objects which were combined via the same relation as in the exemplar; b) an object-pair which possessed the same constituent objects as the exemplar but those were combined via a different relation. Results are in line with what had been found previously in Chapter 2. They showed that correct responses increased with increasing age. Five-year-olds were the only age group to make the correct selection more often than would be expected by chance. These findings suggest that five-year-olds were the only age group to understand that the relation that exists between the constituents is an important component of noun-noun compound meaning. The 2- and 3-year olds appeared to believe that either of the choices was a legitimate basis for extending the compound-noun, as both were object-pairs made up of the same constituent objects as the original exemplar. They did not appear to have considered the presence of the same relation as the exemplar to be a requirement for extending the compound-noun. We can rule out that 2- and 3-year-olds did not chose the correct object pair because they could not remember the relation. In Experiment 2 of Chapter 2, it was shown that 2-year-olds do remember the relations after having been exposed to the same training procedure as in the present study.

Additionally, just as in Chapter 2, the type of relation present in the original exemplar (i.e. HAS or FOR) did not affect the participants tendency to base their extensions on it. Participants were no more likely to correctly extend the compound-noun on the basis of a shared relation if it was a HAS relation rather than a FOR relation or vice-versa.

With these results as a basis we conducted a second experiment to see if actively drawing children's attention to the relation at encoding would allow younger children to comprehend the importance of the relation for the compound's meaning. We replicated the above procedure with a new sample of children, with the exception that the relation was explained to them when they were introduced to the object-pair.

3.3. Experiment 2

3.3.1. Method

3.3.1.1. Participants. Participants were 15 two-year-olds (mean age 32 months, SD=2.4, 8 males), 19 three-year-olds (mean age 42 months, SD=2.7, 13 males), 21 four-year-olds (mean age 53 months, SD= 2.8, 13 males), 18 five-year-olds (mean age 65 months, SD=3, 9 males). Children were recruited from the same region as those in Experiment 1 and the process of obtaining consent was the same. All participants were native speakers of English, and this was their only language.

3.3.1.2. Design. The design was identical to that of Experiment 1.

3.3.1.3. Materials. The materials were identical to those used in Experiment 1.

3.3.1.4. Procedure. The procedure was identical to that of Experiment 1, with the exception that in Part 2, when the object-pair and the compound noun were introduced, the relation between the constituent objects was also explained. For example participants were presented with a HAS relation *kig donka* (see Panel C of Figure 3.1) and told "this is a *donka* that HAS a *kig*, so it's a *kig donka*, have a good look at the *kig donka*, see it's a *kig donka*". If they had been shown a FOR relation *kig donka*, then they would have been told instead that "this is a *donka* that is FOR a *kig*" to highlight the relation. The number of times the compound noun was mentioned was kept constant across participants and was the same as in Experiment 1.

3.3.2 Results

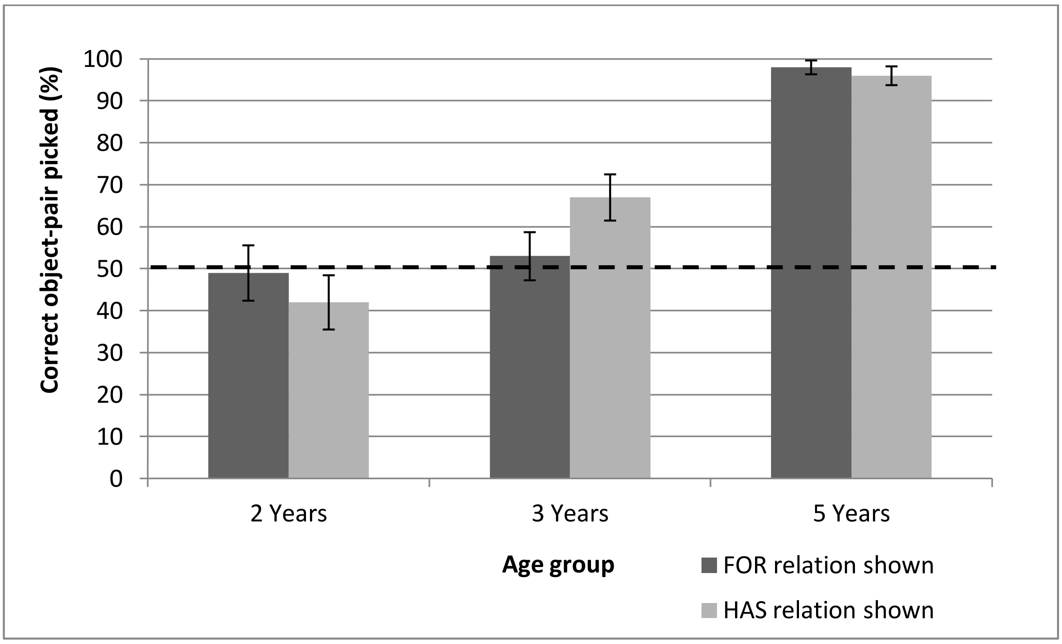


Figure 3.3. Experiment 2: The effect of age group and relation type on object-pair picked when relation is made explicit (50% line marks chance level, error bars represent standard error).

Selection of the matching object-pair represented a correct selection. Figure 3.3 displays the results. The number of correct selections was analysed with a split plot ANOVA with Age group (2-years vs. 3-years vs. 5-years) as a between participants factor and Relation type (FOR vs. HAS) as a within participants factor. The results indicated a significant main effect of Age group ($F(2,49) = 42.7$, $p < 0.001$, partial $\eta^2 = 0.635$) demonstrating that the number of correct selections increased with age. Tukey HSD post-hoc tests indicated that the number of correct selections differed significantly between: 2- and 3-years ($p < 0.05$); 2- and 5-years ($p < 0.001$); and 3- and 5-years ($p < 0.001$). There was no significant effect of Relation type ($F(1,49) = 0.142$, $p = 0.708$, partial $\eta^2 = 0.003$), suggesting that a correct selection did not occur significantly more often for one relation type than the other. The interaction between Age group and Relation type was also not significant ($F(2,49) = 1.687$, $p = 0.196$, partial $\eta^2 = 0.064$.

In addition we conducted planned comparisons of the number of correct selections against chance (3 out of 6 responses). The 2-year-old age group failed to perform at above chance level ($t(14) = - 0.8$, $p = 0.433$). Both the 3-year-old age group ($t(18) = 2.2$, $p = 0.045$)and the five-year-old age group ($t(17) = 31.4$, $p <0.001$) performed at above chance level.

Additionally a repeated measures ANOVA was conducted to investigate the effect of the object-pair type (Coodle Tez vs. Kig Donka vs. Koba Sav vs. Rinta Dax vs. Tidgy Mov vs. Wug Binto) on participants performance, in order to check the generalisability of the results for other objects. The test indicated no significant effect of object-pair type ($F(5,255) = 0.7$, $p = 0.622$, partial $\eta^2 = 0.014$) demonstrating that the particular type of object-pair shown to participants did not affect their performance.

3.3.3. Discussion

Participants were again required to extend a novel noun-noun compound from an exemplar object-pair to one of two object-pairs: a) to a matching object-pair, i.e. an object-pair that possessed the same constituent objects that were combined via the same relation as the exemplar (correct extension), b) to an object-pair which possessed the same constituent objects as the exemplar but those were combined via a different relation. Results showed that, just as in Experiment 1, correct extensions increased with increasing age. However in this experiment, 3-year-olds made correct extensions more often than would be expected by chance. Therefore, verbally explaining the relation has aided younger children in comprehending that the relation is an important part of a compound noun’s meaning. Once again, the relation type of the original exemplar (HAS or FOR) had no effect on whether participants chose to base their extensions on it or not.

3.4. General Discussion

In the current study, we investigated whether explicitly drawing children's attention to the relational component of noun-noun compound meaning at the stage of encoding by verbally explaining the relation, would allow younger children to understand its importance than would otherwise be the case. To achieve this we first of all, using a new sample of participants, confirmed previous results (Chapter 2) that young children (2- and 3-year-olds) do not extend a novel compound-noun on the basis of the relational component. We presented two potential referents: an identical object-pair as the original referent and an object-pair that consisted of the same constituent objects as the original referent, but did not share the same relation type. We then tested a further new sample of children on the same task, with the exception that the relation between the constituent objects of the original compound-noun referent was explained to them during encoding.

Experiment 1 confirmed the conclusion of Chapter 2 that increased understanding of the importance of the relation in compound-noun meaning comes with increasing age. We found that five-year-olds were the only group to extend compound-nouns on the basis of the relational component more often than would be expected by chance. The younger children appeared to not be using the relation that exists between the constituent objects of the original exemplar to guide their choices. Note that by using the same materials as in Chapter 2, we have already shown that 2-year-olds can remember which relation type of a particular object-pair they have seen when being presented with a compound. Their failure is thus not due to a memory problem.

In Experiment 2 we found again that increasing age led to increasing numbers of correct extensions. However we also found that making the relation explicit at encoding had the effect of lowering the age at which children make correct extensions more often than would be expected by chance. Whereas 3-year-olds in Experiment 1 did not make correct extensions at above chance level, in Experiment 2 they did. These findings suggest that making relations explicit at the encoding stage might allow children to encode relational information as an important part of compound-noun meaning at a younger age. Two-year-olds still did not make use of the relational component in their extensions even when it had been highlighted to them at encoding. For them the presence of perceptually identical constituent objects appears all that is necessary for the extension of a compound-noun. Two-year-olds appear to be so strongly focused on perceptual identity of constituent objects that even highlighting the relation is not enough for them to incorporate the relation into the compound's meaning and then use it as a basis for their extensions. This would fit with the findings from Chapter 2, in that 2-year-olds are strongly focused on the perceptual identity of constituent objects as being the key basis for compound-noun meaning.

Our findings also tie in with the 'shape bias' findings that it is the youngest children who are more likely to extend on the basis of perceptual similarity, in this case shape (Gentner, 1978; Merriman, Scott, and Marazita, 1993; Smith et al., 1996; Graham, Williams, & Huber, 1999), and that this bias can be overcome by highlighting a more relevant basis for meaning e.g. function (Kemler Nelson, 1995; Kemler Nelson, 1999; Kemler Nelson, Russel, Duke, & Jones, 2000; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Diesnedruck, Markson, & Bloom, 2003). In both these cases highlighting the appropriate component to base extensions on (relations in the case of noun-noun compounds and function in the case of nouns) allowed younger children to make correct / adult-like extensions than would otherwise have been possible.

In Chapter 2 it was suggested that one possible explanation for why older children are able to make more correct extensions of words is their greater experience with the word class. For example, through experience they would have learned that compound-nouns are defined by the relation that exists between the constituent objects and not the perceptual features of those objects. They would therefore focus on the relation when they encounter a new compound and use it as the basis for extending that compound. Three-year-olds in Experiment 2 did not have any more experience with compound-nouns than those in Experiment 1. However those in Experiment 2 were able to make use of the relation in extending the compounds more often than would be expected by chance, while those in Experiment 2 were not. Explicitly drawing the 3-year-olds' attention to the relation appears to have helped them encode it as an important part of compound-noun meaning, essentially filling in for a lack of experience with the word class. However this was not the case for the 2-year-old age group. Why is this? Perhaps 2-year-olds are so strongly focused on perceptual features as a basis for word meaning that even when the experimenter was highlighting the relation to them they maintained their attention on the perceptual features of the objects involved. Basing meaning on perceptual features as a word-learning strategy may be so strongly ingrained in these youngest children that even highlighting a more suitable alternative is not enough to dissuade them from its use.

The current study adds to what we already know about noun-noun compound learning. On the whole, just like in Chapter 2, we did not find that children were more likely to make use of the relation as a basis for compound-noun meaning when the relation was a HAS relation. We can therefore not offer support for the HAS/LOCATED bias in interpreting compound-noun suggested by Krott, Gagné & Nicoladis (2009) and Krott, Gagné & Nicoladis (2010). Furthermore, our findings do support the idea that despite impressive abilities to produce noun-noun compounds (e.g. Clark, 1981; 1983) and understand their structure (Clark, Gelman & Lane, 1985) from as young as 2-years of age, full understanding of noun-noun compounds is far from complete during the pre-school years. Our findings echo those that suggest that during the pre-school years and beyond understanding of compounds-nouns, and in particular their relational components is still under development (e.g. Nicoladis, 2003; Parault, Schwanenflugel, & Haverback, 2005; Chapter 2 of current thesis).

In conclusion we have investigated whether highlighting the relational component of noun-noun compound meaning at encoding would allow younger children to understand its importance in defining the compound. We found that making the relational component explicit by verbal explanation did help to lower the age at which children base their extensions on it. Therefore highlighting the relational component proved successful in shifting younger children's focus onto it and to thus incorporate it as part of the novel noun-noun compound's meaning.

CHAPTER FOUR

THE BENEFITS OF MULTIPLE EXEMPLARS IN CHILDREN'S SUCCESSFUL MAPPING OF NOVEL VERBS TO ACTIONS

Abstract

Research has suggested that three-year-olds are unwilling to extend novel verbs to new instances when the objects being acted on change, appearing to map verbs onto an object-action interaction. Gentner's structural alignment theory holds that seeing multiple examples of a relation involving different objects allows children to move beyond objects and focus on relational aspects of a scene. The present study investigated the benefit of multiple exemplars in verb learning. Three- and five-year-olds were shown videos of either one exemplar of a novel action performed on a novel object or two exemplars featuring the same action but different objects. Participants were asked to extend the novel verb used to label the video/s to either a scene with the same action as the original exemplar/s or a scene with the same object. Five-year-olds extended verbs correctly, independent of whether they originally saw one or two exemplars. Three-year-olds did this only when they had seen two exemplars. Findings suggest multiple exemplars involving different objects are beneficial in verb learning at the encoding stage. It allows young children to move beyond seeing the object being acted on as being an important part of verb meaning, towards a more adult like understanding that it is the relation between the actor and objects that constitutes the meaning of a verb.

4.1. Introduction

While a great part of learning a first language is learning to label the things that exist in a child's environment, an equally important part is learning to label the relations that exist between these things. People and objects are often related by the actions an individual is performing on an object. In English, verbs are typically used to label these actions. When learning a new verb it is important for children to understand that the verb refers to the action alone. That is, although an individual will be performing the action and may be performing it on an object, the identity of the person and object are irrelevant to the meaning of the verb. Understanding this is essential for children to know how to correctly extend a novel verb to new instances of the action. They need to understand that the presence of a particular individual or object is not necessary for extension; an action will be labelled with the same verb regardless of who is performing it and what objects are involved. This can be difficult for young children. It has been argued that when hearing a verb used to label a dynamic action scene, young children find it difficult to determine the elements of the scene which are significant for the meaning of the verb (see Gentner & Boroditsky, 2001; Imai et al., 2008). Furthermore it has been suggested that a child understanding what a particular verb can be linguistically linked to does not necessarily mean that they will extend that understanding to other verbs. Rather they appear to form "verb islands", where each verb proceeds along its own developmental trajectory regarding what it can be linked to (Tomasello, 1992; Tomasello, 2000).

Previous experimental research involving young children's extension of newly learned verbs to new instances suggests that their understanding of what defines a verb is not complete. Forbes & Poulin-Dubois (1997) report that very young children view the manner in which an action is performed as a crucial part of the verb's meaning. They found that 20-

month-olds are less likely than 26-month-olds to extend familiar verbs (e.g. *pick up*) to new instances where the manner in which the action is performed has changed (e.g. object was picked up with foot, rather than hand). Both Behrend (1990) and Forbes & Farrar (1993) found that young children aged 5 and under view the instrument with which an action is performed as part of the verb's meaning. They were less likely than adults to extend a novel verb to a new instance of the same action when performed using a different instrument. Furthermore, Kersten & Smith (2002) tested the acceptance of scenes as exemplars of newly learned verbs in 3 1/2 to 4-year-olds. These scenes were free to vary with regard to the novel object featured in the scene and / or the motion that the object performed. They found that new scenes in which the motion had changed but the object remained the same were accepted equally often to scenes in which the motion remained the same but the object had changed.

Further research by Imai, Haryu, & Okada (2005) involved testing Japanese speaking 3-year-olds and 5-year olds' ability to map novel nouns onto novel objects and novel verbs onto novel actions. This was achieved by presenting participants with video clips that showed an actor performing a novel action on a novel object. Participants either heard the scene labelled with a novel noun or a novel verb. They were then asked to extend the noun or verb to either a scene depicting the same action being performed on a new novel object or a scene depicting a new novel action being performed on the same object. The scene depicting the same action being performed on a different novel object was the correct response when the participant had heard a novel verb, while the scene depicting a new novel action being performed on the same object was the correct response when the participant had heard a novel noun. The authors found that while 5-year-olds could correctly extend both novel nouns and verbs, 3-year-olds could only extend novel nouns. In the case of verbs, they randomly picked the two test scenes. This suggests that 3-year-olds were unable to extend a novel verb to a new instance of the same action when the object being acted on had changed. Therefore the authors concluded that 3-year-olds understand that nouns are generalised on the basis of object identity, regardless of actions being performed on the object, while they do not understand that verbs are defined by actions alone, regardless of objects involved. This finding thus suggests that 3-year-olds tend not to map novel verbs onto only the action present in a scene; they rather tend to map the verb onto an object-action interaction. In other words, they think that both the action and the object that were present when the verb was originally used must be present for an event to represent a new instance of that verb. Importantly, this finding is not specific for Japanese children. Imai et al. (2008) reported equivalent findings for English speaking children of the same age using the same procedure.

The research presented so far has concentrated on the fast mapping of verbs from a single exemplar to a new instance of a verb. While this tells us something important about the challenges that children face when first encountering a novel verb and their first (mis)-interpretations, young children’s do not seem to use verbs inappropriately. The question therefore arises how young children overcome their incorrect interpretations of novel verbs. Would their understanding benefit from viewing multiple exemplars, or more precisely from exposure to just one additional exemplar?

The Structural alignment theory proposed by Gentner (e.g. Gentner & Namy, 2006) suggests that comparing two things leads to a search for commonalities between their conceptual representations. The authors suggest that even if this comparison is initially prompted by noticing perceptual similarities it leads to noticing deeper relational commonalities. Indeed relational commonalities are preferentially highlighted by comparison (Gentner & Markman, 1997). For example in Markman and Gentner (1993), adults were shown a picture of a truck towing a car and a picture of a car towing a boat. When participants were simply asked to indicate which feature in the second picture matched the car in the first, they chose the perceptual match i.e. the car. However when first asked to compare the pictures, rate the similarity and then indicate which feature in the second picture matched the car in the first, participants chose the boat. That is they chose the relational rather than the perceptual match.

Making comparisons has also been shown to lead children to look past attention grabbing perceptual similarities and to notice deeper semantic commonalities. Verbal descriptions or labelling of stimuli can trigger such comparisons (Gentner & Namy, 2006). For instance, Gentner & Namy (1999) found that 4-year-old children would extend a novel noun (e.g. *kig*) used to label an object (e.g. *apple*) to a perceptually similar object (e.g. *balloon*) over a semantically similar object (e.g. *banana*). However when the noun was used to label two objects (e.g. *apple* and *pear*.), children instead extended the noun to the semantically similar object (*banana*). This is particularly remarkable as both the apple and pear were more perceptually similar to the balloon, effectively providing the child with more evidence for choosing on the basis of perceptual similarity. This experiment shows that providing the opportunity to compare two exemplars (*apple* and *pear*) highlights semantic commonalities, for instance function, which is the basis for category membership that adults use.

In a further study Namy & Gentner (2002) compared children's extensions on the basis of category membership when two objects had been given the same name compared to when they had been given different names. They asked 4-year-olds to extend category membership from two perceptually similar objects (e.g. an *apple* and a *pear*) to either a perceptual match (e.g. a *balloon*) or a category match (e.g. a *banana*). Children picked the perceptual match if the two objects had been given different novel names, but picked the category match if they had been given the same name. This further strengthens the claim that labelling objects with the same name supports the comparison process (Gentner & Namy, 2006).

The present study focuses on young children's ability to make use of structural alignment processes when extending novel verbs to new instances. Similar to Gentner and Namy's study (1999), we investigated whether children shift attention away from perceptual similarities towards relational similarities when being shown multiple exemplars of verbs instead of just one exemplar. We showed young children one or two exemplars of novel action scenes and labelled them with the same novel verb to see whether a single additional exemplar leads children to map the verb onto the action alone rather than an object-action interaction as in Imai et al. (2005) and Imai et al. (2008). Thus, we investigated whether an additional exemplar focuses children's attention on the relational component of a scene, i.e. the action.

The aim of our study is somewhat similar to that by Childers (2011) who had previously investigated the benefit of multiple exemplars in verb learning. But there are important differences. In Childers' study young children were shown a target event, e.g. someone rolling a melon down through a flap on top of an opaque box, resulting in the melon no longer being visible. Participants in an 'action' group were then shown three scenes which preserved the action but not the result, e.g. a melon being rolled down a wooden incline; a melon being rolled down a curved pipe; and a melon being rolled down a foil tube. The melon was always visible at the end of the action. Participants in a 'result' group were shown three scenes which preserved the result but not the action, e.g. a melon being obscured from view in three different ways. In the testing phase participants were given the opaque box from the target event, a new ramp and a piece of cloth, and the melon. They were asked to carry out the verb, i.e. they were asked "can you *verb* it?" The testing phase for each trial occurred immediately after the learning phase, so memory demands were minimised. The study found that children were more likely to imitate the action response when they had seen multiple examples of the action and more likely to imitate the result response when they had seen multiple examples of the result.

The results of Childers (2011) suggests that participants were more likely to map the novel verb onto either the action or the result depending on which they had seen the most of. However, Childers did not compare children's verb extensions when being exposed to multiple exemplars compared to when being exposed to a single exemplar, even though she compared the multiple exemplar condition against a condition in which the children saw the exact same action with the same objects performed several times. She therefore did not compare fast mapping against exposure to multiple exemplars. Also, her study does not address whether seeing multiple examples involving different objects allows children to break the action-object mapping link. This is because the object being acted on always remained the same in her study. The children always saw the action performed on the melon in all enacted scenes and were given the melon themselves at test. So while the authors find that participants who saw multiple examples of the action were more likely to re-enact the action at test, they had not only seen the action repeated four times while hearing the novel verb, they had also seen the same action performed on the same object (i.e. the melon being rolled) four times. Because participants never heard the novel verb used to label the action without the presence of the melon and were given the melon at test when they performed the action, children might have mapped the verb onto an action-object interaction (as found in Imai et al. (2005) and Imai et al. (2008)).

Furthermore Maguire et al. (2008) found that showing 2 and half to 3-year-olds four videos featuring the same actor performing the same intransitive action resulted in more correct extensions of novel verbs than four videos featuring different actors. Similarly to Childers (2011) the test phase during which verbs were extended occurred immediately after the training phase for each trial, meaning memory demands were minimised. Again there are important differences between our study and Maguire et al. (2008). Their study makes use of intransitive, rather than transitive actions. They compare conditions in which participants view four videos. A comparison is not made between a single exemplar condition and a multiple exemplar condition. We focus on the benefit of just a single additional exemplar. And most importantly the results of Maguire et al. (2008) do not assess whether the object-action interaction mapping of young children can be broken through the use of multiple exemplars.

In contrast to Childers (2011) and Maguire et al. (2008), we investigated in Experiment 1 whether seeing two action scenes of a novel action side by side and hearing them labelled with the same novel verb would lead to correct mapping of verbs to the action only, therefore breaking the action-object interaction mapping of verbs found by Imai et al. (2005) and Imai et al. (2008). We presented 3- and 5-year-old children with one or two exemplar videos of novel actions involving novel objects. We then tested whether they extended the verbs used to refer to the actions to either the same action with a different object (= correct extension) or the same object with a different action. If participants extended the novel verb on the basis of the action instead of the object when having seen multiple exemplars, but not when having seen a single exemplar, then this would suggest that the act of comparison across the two exemplars allowed children to map the verb onto the action only, rather than an action-object interaction. If participants extended the novel verb on the basis of the object in both the single and multiple exemplar conditions then this would suggest that they mapped the verb onto the object. If participants randomly chose between target videos then they might have mapped the verb onto an action-object interaction, believing that both the action and object present at encoding need to be present to extend the verb.

Based on the findings of Imai et al. (2005) and Imai et al. (2008) we expected that 5-year-olds would correctly extend novel verbs on the basis of a shared action in both the single and multiple exemplar conditions. But their performance might be improved in the multiple exemplar condition. Three-year-olds, on the other hand, have been found not to be able to correctly extend novel verbs in the fast mapping paradigm, but to respond randomly to the test scenes (Imai et al., 2005; Imai et al., 2008). We therefore expected them to show the same pattern as in previous studies when seeing only a single exemplar. Based on the findings of Gentner and colleagues regarding the benefits of comparison across multiple exemplars in noun learning, we expected that 3-year-olds would benefit from seeing multiple exemplars and thus correctly extend a novel verb to a scene that shares the same action with the training scene.

Experiment 1 was followed up with an experiment that aimed to investigate the particular circumstances under which multiple exemplars are beneficial to verb learning (Experiment 2). Using the same procedure as in Experiment 1, the first condition of Experiment 2 tested whether seeing two exemplars would be beneficial if both of the exemplars were identical (i.e. two identical action scenes featuring the same action, object, and actor). The second condition tested whether multiple exemplars that varied along more than one dimension, namely actor and object, would be beneficial.

4.2. Experiment 1

4.2.1. Method

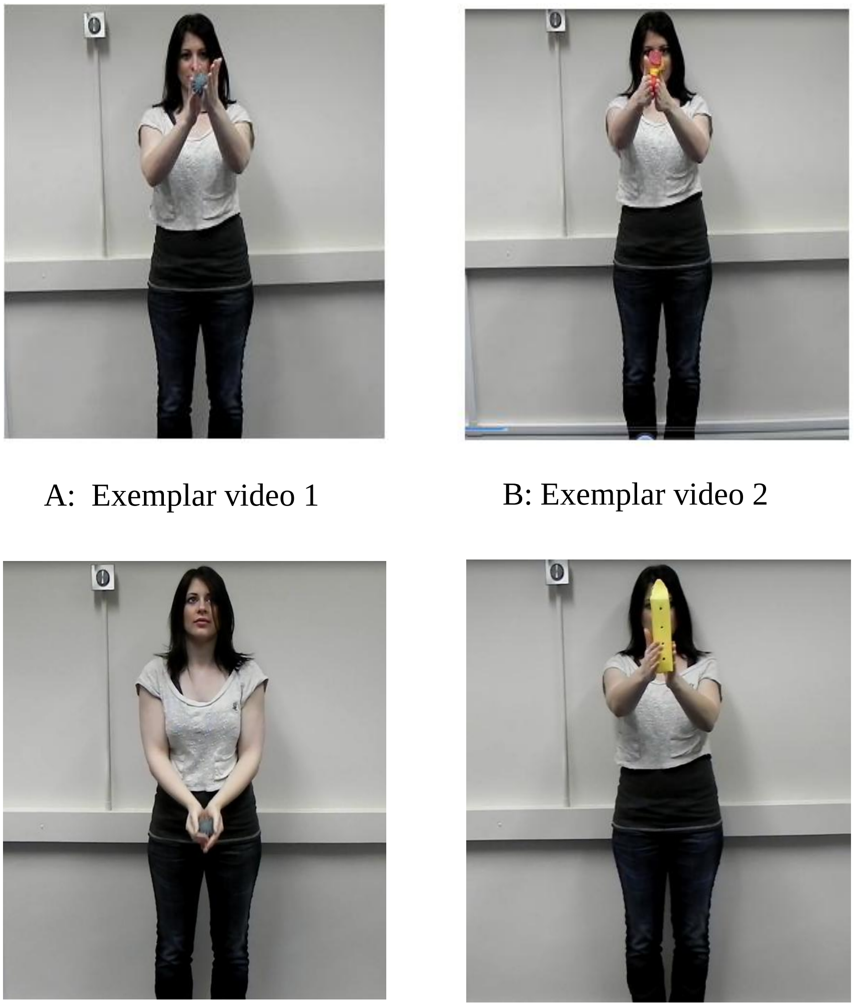
4.2.1.1. Participants. Fourty three-year-olds (mean age 41.6 months, *SD*= 3.4) and 40 five-year-olds (mean age 65.0, months, *SD*= 3.6) took part in the experiment. Participants were recruited from nurseries and schools in the West Midlands area of the United Kingdom. All nurseries and schools who participated in the study served families from areas of the same level of socioeconomic status. Permission to participate was granted by either the head teacher or the owner of the nursery. Parental consent was obtained when requested by the head teacher / nursery owner. All participants were native monolingual speakers of English.

4.2.1.2. Design. The independent variables tested were Number of Exemplars (single vs. multiple) and Age Group (3 years vs. 5 years). The dependant variable was number of correct verb extensions. The experiment had a between subjects design, meaning that half of the 3- and 5-year-olds took part in the single exemplar condition, the other half in the multiple exemplar condition. This design was chosen in order to avoid carry-over effects between the two conditions.

4.2.1.3. Materials. A laptop computer was used to display Microsoft Powerpoint© slides containing either one video in the centre of the screen or two videos playing side by side. All videos were the same size regardless of which condition they featured in: 15cm x 11cm. Each of these videos displayed an actor repeatedly performing a novel action on a novel object for a 30 second period (around 20 repetitions of the action). Six novel verbs (blicking; gloobing; rinting; zanging; triting; plewing) were used to label six novel actions (for details of the actions see Appendix C). Most were closely based on the original actions used by Imai et al. (2005). All actions were iterative, durative and involved direct contact with the object.

4.2.1.4. Procedure. Participants were sat down in front of the laptop computer and told “we’re going to play a game on the computer. We’re going to look at some videos of some people doing some funny things.” To begin with the participant took part in a pair of warm up trials. Participants experienced the same warm up trials regardless of whether they were in the single or multiple exemplar groups. The first warm up trial involved them being shown a picture of a dog and a picture of a cat side by side. The child was asked to point at one of the pictures, e.g. “show me the dog”. The second warm up trial involved the participant being simultaneously shown a video of an actor jumping up and down and a video of the same actor going from a standing to a sitting position, side by side for 30 seconds. The child was asked to point at one of the videos e.g. “show me the lady jumping”. Which picture or video the child was asked to label in each of the warm up trials was randomised across participants, but participants were always asked to point at one picture / video on the left and one on the right. In this way we ensured that participants were willing and able to point to both sides of the screen. Participants only proceeded onto the main task if they passed both warm up trials.

Participants were presented with six experimental trials. Each trial consisted of a training slide followed by a test slide. Participants saw either one (single exemplar condition) or two exemplars (multiple exemplar condition) on the training slides, but were presented with the same test slides. They were randomly placed into either the single exemplar condition or the multiple exemplar condition.



A: Exemplar video 1

B: Exemplar video 2

C: Test video 1

D: Test video 2

Figure 4.1. Example videos for Experiment 1. Participants in the single exemplar condition saw Panel A at training and Panel C and D at test. Participants in the multiple exemplar condition saw Panel A and Panel B at training and Panel C and Panel D at test.

Training - single exemplar condition. The training slide consisted of a single video in the centre of the screen showing a female actor performing a novel action on a novel object. For instance, a woman was holding a novel object and rolled it backwards and forwards between the palms of her hands (see Panel A of Figure 4.1). This video was shown for thirty seconds and consisted of the actor repeatedly performing the action. While the video was being shown the experimenter pointed at the video and labelled the action three times, at ten second intervals e.g. “look she is blicking”.

Training - multiple exemplar condition. The multiple exemplar condition was identical to the single exemplar condition with the exception that the participants saw the novel action being performed on two, rather than one novel object, and heard it labelled with the same novel verb in both cases. Thus, the training slide in the multiple exemplar condition consisted of two videos being played side by side simultaneously for a thirty second period. The video on the left side of the screen consisted of a female actor repeatedly performing a novel action on a novel object, e.g. a woman was holding a novel object and rolled it backwards and forwards between the palms of her hands (see Panel A of Figure 4.1). The video on the right side of the screen consisted of the same actor performing the same action on a different novel object (see Panel B of Figure 4.1). While the videos were being shown, the experimenter labelled the action in each video whilst pointing at the videos e.g. “look she is blicking, and look she is blicking”. This occurred at 10 second intervals, resulting in each video being labelled three times in total.

Testing. On the test slide two videos played side by side simultaneously. The foil (same object-different action) video showed the same female actor using the same object used in the corresponding training but with a new novel durative and iterative action (see Panel C of Figure 4.1). The target (same action-different object) video showed the same female actor carrying out the same action seen during the corresponding training but with a new novel object (see Panel D of Figure 4.1). Which video appeared on which side was randomised across participants. While the videos were playing, the experimenter asked the participant to point to the video that featured the novel verb which they heard during the presentation of the training slide: “can you show me blicking?, which video is she blicking in?, only one, can you show me?” The videos were 30 seconds long, although no participant required the full 30 seconds in order to produce a response. As soon as the participant pointed to one of the videos the experimenter moved onto the next trial.

4.2.2. Results

Selecting the video containing the action originally labelled with the novel verb was considered a correct response. Figure 4.2 displays the results.

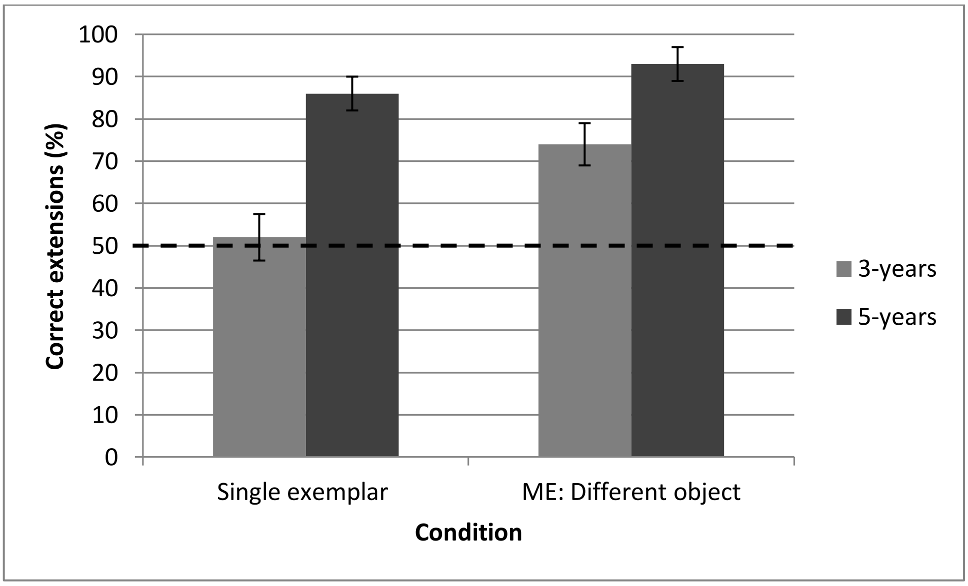


Figure 4.2. Experiment 1: The effect of age group (3-years vs. 5-years) and number of exemplars shown during training (Single Exemplar vs. Multiple Exemplars (ME) with different objects acted upon) on correctly extending a novel verb on the basis of shared action. 50% line marks chance level. Error bars represent standard error.

The number of correct selections was analysed with a between subjects ANOVA with Age Group and Number of Exemplars as between participant factors. The test indicated a significant main effect of Age Group ($F(1, 76) = 31.9$, $p < .001$, partial $\eta^2 = .296$), with more correct responses for 5-year-olds than 3-year-olds. There was a significant effect of Number of Exemplars ($F(1, 76) = 9.8$, $p = .002$, partial $\eta^2 = .115$), with more correct responses in the multiple exemplar condition than in the single exemplar condition. The interaction between Age Group and Number of Exemplar was not significant ($F(1, 76) = 2.9$, $p = .093$, partial $\eta^2 = .037$), even though there was a trend for 3-year-olds to improve their performance more strongly in the multiple exemplar condition. But this is likely due to a ceiling effect for five-year-olds in the multiple condition.

Additionally, planned comparisons of the number of correct selections against chance were conducted (3 out of 6 responses) within each age group for each condition. Three-year-olds in the single exemplar condition did not make the correct selection any more often than would be expected by chance, $t(19) = 0.3$, $p = 0.797$, but they did so in the multiple exemplar condition, $t(19) = 5.9$, $p < 0.001$. Five-year-olds' number of correct selections was significantly above chance, both in the single exemplar condition, $t(19) = 7.8$, $p < 0.001$, and in the multiple exemplar condition, $t(19) = 15.0$, $p < 0.001$.

4.2.3. Discussion

In Experiment 1 participants were required to extend a novel verb to either a scene that shared the same action as the training scene, but featured a different object (correct extension), or to a scene that featured a different novel action, but the same object as the training scene. It was found that 5-year-old children were able to make correct extensions, both when they had been shown two scenes featuring the same novel action but different novel objects, and to a lesser extent when they had been shown only one of the two scenes. Three-year-old children were unable to make correct extensions of a novel verb when they had been shown only one video exemplar. But when they had been shown two exemplar videos featuring the same novel action but different objects, they were able to correctly extend the novel verb.

Our findings with regards to the single exemplar condition replicate the results of the fast mapping paradigm by Imai et al. (2008). Five-year-olds have clearly understood that it is the action alone which defines the verb and only the action needs to be present in a new scene in order to extend the verb; the presence of a particular object is not required. On the other hand and as suggested by Imai et al. (2005) and Imai et al. (2008), three-year-olds likely mapped the verb onto an action-object interaction, believing that both the original action and object need to be present in order to extend the verb. The results of our multiple-exemplar condition suggests that the use of just one additional exemplar did break 3-year-olds' action-object interaction mapping. Now they were able to map the novel verb onto the action only.

It could be argued that the correct choice for verb extension in this experiment, and indeed in the Imai et al. (2005) procedure upon which it is based, does not reflect verb extension on the basis of shared action alone, as the same actor is present in both the original exemplar and in the test scene. However previous findings speak against this interpretation. Imai et al. (2005) also tested whether 3-year-old children were willing to extend a novel verb to a scene in which the action and object remained the same, but a different actor was performing the action. They found that 3-year-olds were overwhelmingly willing to extend the verb to these scenes featuring a different actor. These findings indicate that children as young as 3-years do not believe that the actor performing the action is part of the verbs meaning and therefore the same actor does not need to be present in order to extend the verb. Similar findings regarding 3-year-olds willingness to extend verbs to new actors performing the same action are also provided by Golinkoff, Jacquet, Hirsh-Pasek, & Nandakumar (1996).

It is therefore unlikely that the children in our experiment mapped the verb to an action and actor combination.

4.3. Experiment 2

Having established that 3-year-olds benefit from the exposure to two exemplars to break the action-object link, the questions arises as to how similar or different these exemplars can or need to be to aid verb learning. In Experiment 2 we therefore tested two further conditions which both featured two exemplars, but with varying similarity between the exemplars.

While it has been found here and in previous studies that multiple exemplars aid the understanding of a novel word, an alternative argument has been posited in the literature, namely that less information can facilitate successful extension better than more information. Casasola (2005) found that when required to extend the support relation *on*, 14-month old children were able to do so when they had been shown two exemplars (e.g. two object-pairs consisting of one object on top of another), but not when they had been shown six exemplars. Additionally, Maguire et al (2008) found that 2 and half to 3-year-olds were better able to extend novel verbs used to label novel intransitive actions when they were shown the same video 4 times (i.e. same actor performing the same action) than when they were shown 4 videos each depicting a different actor performing the same novel action. Maguire et al. (2008) link their conclusion that less information may be beneficial to similar findings regarding less information being better for the formation of non-linguistic relational categories (Kersten & Smith, 2002; Casasola & Cohen, 2002; Quinn, Poly, Furer, Dobson, & Narter, 2002). Maguire et al. (2008) argues that these studies indicate that children focus first on objects in a scene and only later on relations, even when learning verbs. Therefore the use of different objects may act to keep children's focus on objects. Thus, the use of fewer objects might improve children's focus to relational information and therefore actions.

With this in mind we aimed to see if multiple exemplars featuring less information, namely two identical videos would be more beneficial to verb extensions than the videos featuring different objects in Experiment 1. We carried out a condition with 3-year-olds that was identical to the multiple exemplar condition from Experiment 1, with the exception that rather than seeing two exemplars featuring the same action being performed on two different objects, participants were presented with the same video twice (= Condition 1 – Multiple Exemplar (ME): Same exemplar twice).

It is possible that both too little and too much information is detrimental to correct extensions. This was found by Waxman & Klibanoff (2000) with regard to adjectives. In their study 3-year-old children were required to extend novel adjectives used to label pairs of objects. They found that participants correctly extended adjectives if the exemplar objects varied along only one dimension, e.g. if the original objects varied in whether they were visually transparent or opaque, but were from the same base level category (e.g. plates); or if the original objects varied in terms of base-level category membership, but were both transparent. But if nothing was varied e.g. both original exemplars were transparent and from the same base-level category, and when too much was varied, e.g. when the original exemplars varied in terms of transparency and were from different base level categories, children failed to make correct extensions.

When learning a new verb, children often hear the verb used for different individuals performing an action on different objects. Thus, not only the object but also the actor tends to change across instances. Despite findings that young children do not encode the actor performing the action as a part of verb meaning itself (e.g. Golinkoff et al., 1996; Imai et al.,

2005) this is still another aspect of the learning environment that is free to vary. Does this additional variability across instances have an effect on their understanding of what the new verb refers to? In order to investigate whether varying an additional dimension to object identity is detrimental or beneficial to verb learning we conducted another condition, again with 3-year-olds. The procedure was identical to that of the multiple exemplar condition in Experiment 1 with the exception that the two training videos featured not only two different objects but also two different actors (= Condition 2 - Multiple Exemplars (ME): Different actor and different object).

4.3.1. Method

4.3.1.1. Participants. Twenty 3-year-olds participated in Condition 1 (mean age 42.5 months, *SD*= 3.4) and another sample of twenty 3-year-olds participated in Condition 2 (mean age 41.9 months, *SD*= 4.0). None of the participants from either of the conditions in Experiment 2 had participated in Experiment 1. Participants were recruited from nurseries of the same geographical location, serving families from areas of the same level of socioeconomic status as those in Experiment 1, and the procedure for obtaining consent remained the same. All participants were native monolingual speakers of English.

4.3.1.2. Materials. Experimental materials were identical to those of Experiment 1, with the exception that Condition 2 included videos featuring a different actor.

4.3.1.3. Procedure. Participants took part in the same warm up procedure as in Experiment 1.

Condition 1 - Same exemplar twice condition. This condition was identical to that of the multiple exemplar condition from Experiment 1, with the exception that rather than seeing two different exemplars on the training slide, participants saw the same exemplar twice, i.e. one on each side of the screen.

Condition 2 – Multiple Exemplars (ME): Different actor and different object. This condition was identical to the multiple exemplar condition in Experiment 1, with the exception that on the training slide, rather than seeing the same female actor performing an action on two novel objects in the two videos, two different female actors were featured. Therefore, the only difference to the example shown in Figure 4.1 was that a different actor appeared in Panel B. The test slides were identical to those used in the single exemplar condition (see Panels C and D of Figure 4.1). That meant that in the test phase participants saw two videos featuring the same actor, namely one of the actors featured in the training slide. This actor performed either the same action as in the training slide on a novel object not previously seen, or she performed a novel action not previously seen on one of the objects from the training videos.

4.3.2. Results

As in Experiment 1, selection of the video containing the action originally labelled with the novel verb was considered a correct response. Figure 4.3 displays the results, together with the Single Exemplar and the Multiple Exemplar - Different Object conditions of Experiment 1. A between-subjects ANOVA including all of the conditions shown in figure 4.3 found a significant difference in performance across conditions ($F(3, 76) = 3.7$, $p < .05$, partial $\eta^2 = .126$). We then conducted t-tests to compare the two new conditions with the two old conditions and accordingly applied Bonferroni-adjustments to alpha ($0.05/ 4 = 0.0125$).

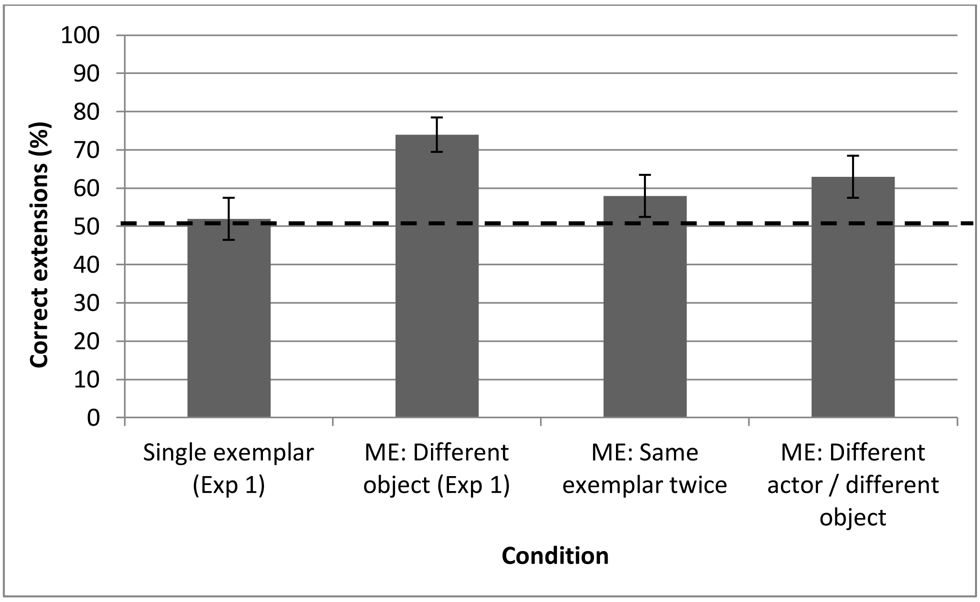


Figure 4.3. Percentage of correctly extended novel verbs depending on training condition, including conditions featuring a single exemplar and various types of multiple exemplars (ME = Multiple exemplars). 50% line marks chance level. Error bars represent standard error.

Single exemplar vs. ME: Same exemplar twice. A *t*-test was carried out to determine if three-year-olds had a different number of correct responses in the Single Exemplar condition of Experiment 1 versus the ME: Same exemplar twice condition in Experiment 2. However, there was no significant difference (*t*(38) = -0.7, p = .463).

ME: Same exemplar twice vs. ME: Different object. A t-test was carried out to determine if three-year olds had a different number of correct responses in the ME: Different objects condition of Experiment 1 versus the ME: Same exemplar twice condition in Experiment 2. There were significantly fewer correct responses in the ME: Same exemplar twice condition, compared to the ME: Different object condition (*t*(38 = 2.7, p = .01).

Single Exemplar vs. ME: Different actor and different object. A *t*-test was carried out to determine if three-year-olds had different number of correct responses in the Single exemplar condition in Experiment 1 compared to the ME: Different actor and different object condition. But there was no significant difference ($t(38) = -1.3$, $p = .21$).

ME: Different object vs. ME: Different actor and different object. A *t*-test comparing the multiple exemplar condition from Experiment 1 (different objects and same actor) with the ME: Different actor and different object condition indicated a trend for worse performance when different actors and different objects were presented compared to when only different objects were presented, even though this was not significant when adjusting the alpha level for multiple comparisons ($t(38) = 2.0$, $p = 0.048$; alpha = 0.0125).

Comparisons against chance. We conducted planned comparisons of the number of correct selections against chance (3 out of 6 responses). It was found that the ME: Different actor and different object condition ($t(19) = 2.6$, $p = .019$), led to correct selections significantly more often than would be expected by chance. The ME: Same exemplar twice condition, however, did not, ($t(19) = 1.6$, $p = .119$).

4.3.3. Discussion

In Condition 1 of Experiment 2 three-year-old children were shown the same video twice, side by side, featuring an actor performing a novel action on a novel object. As in Experiment 1, they were asked to extend a novel verb either to a scene which shared the same action as the original referent scene, but featured a different object (correct extension), or to a scene which featured a different novel action, but the same object as the original scene. It was found that the 3-year-old children were no more likely to extend the novel verb correctly having seen the same exemplar twice, than they were when they had seen one exemplar only (Experiment 1). Furthermore, when comparing multiple exemplar conditions, they were significantly more likely to correctly extend the novel verb when they saw multiple exemplars that varied in object acted upon than when they saw two identical exemplars. Just as when having seen only one exemplar, 3-year-olds who saw the same exemplar twice selected randomly between the two videos. This suggests that just seeing the same information more than once did not allow 3-year-old children to break their tendency for action-object interaction mapping. That also means that it is not merely seeing two videos, regardless of content, which improved performance in the Multiple Exemplar – Different Object condition in Experiment 1.

In Condition 2 of Experiment 2, three-year-old children were shown two exemplar videos that shared the same action, but differed not only in terms of object acted upon but also in terms of actor performing the action. It was found that 3-year-olds were no more likely to correctly extend the verb in this condition compared to having seen only one exemplar. They also tended to make correct verb extensions less often than those who saw multiple exemplars in which only the object varied (in Experiment 1). Nevertheless, they did extend the verb correctly more often than would be expected by chance. Our findings therefore suggest that seeing multiple exemplars that differ in terms of both object and actor may not be as beneficial to breaking the action-object interaction link as seeing multiple exemplars that differ only in terms of the object.

4.4. General discussion

The current study aimed to investigate the possible benefits of multiple exemplars in aiding young children to correctly map novel verbs to the action component of a scene only, and therefore to break the action-object interaction link. We were especially interested in whether a single additional exemplar would be enough to do so. We conducted experiments that asked young children to extend novel verbs to either scenes that maintained the action of the original exemplar, but not the object, or to scenes that maintained the object of the original exemplar, but not the action. We varied the number and content of exemplar scenes featuring the novel verb.

In Experiment 1 we found that 5-year-olds could correctly extend a novel verb to a new scene that maintained the action but not the object of the original referent, whether they had been shown one or two exemplars of the verb. They did however benefit from being shown multiple exemplars of the verb featuring different objects, being more likely to correctly extend the verb than if they had seen only one exemplar. Three-year-olds on the other hand were not able to correctly extend the novel verb if they had seen only one exemplar. But when they were shown two exemplars with different objects they, like 5-year-olds, could correctly extend the novel verbs to scenes that maintained the action of the original referent scenes. But the performance of 3-year-olds in the multiple exemplar condition was not as good as that of 5-year-olds. Our findings therefore suggest that both 3- and 5-year-old children did benefit from the use of multiple exemplars when first encountering a novel verb. For 3-year-olds it had allowed them to actually correctly map the novel verb onto the action component of a scene. For 5-year-olds it simply improved their ability to do this. Perhaps providing them with more information increased the certainty with which they mapped verbs to actions only.

Condition 1 of Experiment 2 demonstrated that children did not benefit from the use of multiple exemplars when they were just shown the same information twice. It is thus important to vary the object in the scene to break that action-object interaction link. This result additionally shows that the results of the first experiment cannot be attributed simply to children having seen two videos during training rather than one, regardless of content. Condition 2 of Experiment 2 showed that varying another component across the two exemplars, in this case actors, may impede the beneficial effect of multiple exemplars, even though it did not completely take away this effect.

Through these experiments we have shown that the use of multiple exemplars at the first encountering of novel verbs is beneficial to correct verb extensions and therefore to young children's understanding of verb meaning. Our findings support the structural alignment theory proposed by Gentner and colleagues, in particular the idea put forward by Gentner & Namy (2006) that labels are invitations to compare two scenes and that making comparisons highlights relational commonalities, allowing children to look past attention grabbing perceptual features. In a similar vein to the findings of Gentner & Namy (1999) regarding noun extensions to category members, we have found that allowing children to make comparisons across two scenes labelled with the same novel verb, allows young children to focus on the part of the scene which relates the actor and the object acted upon i.e. the action, and understand that the object is not part of the verb's meaning. Our findings therefore suggest that by showing young children multiple exemplars and allowing them to engage in structural alignment they can be bootstrapped up to a level of verb understanding more akin to that of older children when encountering a single exemplar.

Our findings add to those of Childers (2011) regarding the benefits of multiple exemplars in verb learning. While Childers had shown that commonalities between multiple exemplars can lead children in interpreting a novel verb as referring to an action or a result, our findings demonstrate the benefit of multiple exemplars to break the action-object interaction link. Our finding also shows that the multiple exemplar benefit for verb learning is achieved by presenting just two exemplars that differ in terms of the object that is acted upon.

The result of our study that participants did not benefit from multiple exemplars when they just saw the same information twice suggests that less information is not necessarily better than more, and children do not necessarily benefit from just seeing the same thing twice. Our findings therefore contradict those of Maguire et al. (2008) who concluded that seeing the same information / scenes multiple times was more beneficial in enabling correct verb extensions in young children, than seeing scenes where the action stayed the same, but other components varied (in their case the actor who performed the action). There are at least three possible reasons why we did not see a beneficial effect of repeating the same information, whereas Maguire et al. (2008) did. First, it might be due to the differing number of presentations. We showed children the same video twice, while Maguire et al. (2008) showed participants the same video six times. Perhaps there is a certain number of repetitions of the exact same information that children need before they are able to focus on the particular components that are relevant for verb meaning. Second, the presentation method we used may have better enabled children to carry out structural alignment and more fully benefit from multiple exemplars in which the content varied. The structural alignment process suggested by Gentner and colleagues works on the basis of making comparisons across scenes. In our study participants were able to see the two exemplars occurring side by side, whereas in Maguire et al (2008) their exemplars were shown successively in isolation. Our study therefore might have made comparisons between videos easier. Third, our study differed from that of Maguire et al. (2008) in terms of the type of verbs used. While Maguire et al. (2008)

presented intransitive verbs, we used transitive ones. In other words, in Maguire et al.'s study no objects appeared in the videos. It might be the case that the action-object link is particularly difficult to break and that the repetition of exactly the same video might not benefit the children's understanding. To clarify which of these options is correct is beyond the aim of the present study. But importantly, less or more information beyond variations along a single dimension appears to be beneficial only under certain circumstances. Future studies need to investigate what exactly these conditions are.

One further insight into this issue is provided by Condition 2 of our Experiment 2, a multiple exemplar condition where scenes varied along two dimensions (object acted upon and actor). We found that this condition did not lead to better performance than the single exemplar condition. Therefore, while multiple exemplars featuring too little information (identical videos) may fail to produce beneficial results, varying the exemplars along too many dimensions may also be detrimental to their effectiveness. This suggests that for multiple exemplars to be beneficial to break the action-object interaction link, these exemplars should be varied along only one dimension, i.e. the object. In this respect, our findings are more similar to those of Maguire et al. (2008) in that too much information can be detrimental.

The finding that varying exemplars along only one dimension is optimal is also in line with that of Waxman & Klibanoff (2000) who investigated the beneficial effects of multiple exemplars in adjective learning. They found that 3-year-olds would correctly extend novel adjectives if exemplars varied along only one dimension, but failed to do so if the exemplars varied along more than one dimension or did not vary along any dimension. Leaving Maguire et al.'s (2008) findings aside, it therefore appears that for multiple exemplars to be most beneficial in word learning the exemplars should vary along one dimension and one dimension only.

The question arises why 5-year-olds, unlike 3-year-olds are able to correctly map novel verbs to actions when shown a single exemplar, i.e. with minimal exposure in a fast-mapping paradigm. It has been shown that syntactic cues can aid fast mapping of verb meaning (Imai, et al. 2008). One possibility is therefore that 5-year-old are more able than 3-year-olds to make use of morphological and syntactic cues. They may be better able to make use of the suffix “-ing” on the end of the verb to direct their attention towards the action component of the scene and away from the object, as they are more confident that object names don’t tend to end in “-ing”, while actions do.

Additionally or alternatively, 5-year-olds may in general be more able to shift their attention away from attention-capturing perceptual features during word learning, and instead focus more easily on the relational features of a scene when extending names to novel scenes. This general trend can be seen in other areas of word learning, for instance, in findings relating to the ‘shape bias’. Young children tend to generalise nouns on the basis of shape, a perceptual feature, when having minimal exposure to the referent of the noun. And with age they come to generalise nouns on the basis of function, a relational feature (e.g., Gentner, 1978; Merriman, Scott, & Marazita, 1993; Smith, Jones, & Landau, 1996). Furthermore, when extending novel noun-noun compounds to new exemplars, children’s basis for extensions has been shown to shift from non-relational aspects (the perceptual features of the object-pair that the compound refers to) to relational aspects (the relation between the objects in the pair) between the ages 2 and 5 (Chapter 2). Importantly, however, such a bias to attention-grabbing perceptual features can be overcome. For instance, the shape bias can be overcome when children experience the function themselves (Kemler Nelson, 1999; Kemler

Nelson, Russel, Duke, & Jones, 2000). And, similar to the present study, multiple exemplars can lead children to extend novel names to objects that are semantically related (same category, e.g. apple and banana) instead of objects that share a similar shape (e.g. apple and balloon; Gentner & Namy, 1999).

It should be understood that we are not arguing that 3-year-old children are unable to perceive relations. There is much evidence that very young children do possess sensitivity to the conceptual components required for the acquisition of relational terms, including verbs (Pruden et al, 2012; Goksun, Hirsh-Pasek, & Golinkoff, 2010; Pruden, Hirsh-Pasek, & Goliknoff, 2008; Golinkoff & Hirsh-Pasek, 2008; Waxman et al., 2009; Arunachalam & Waxman, 2011). We are rather arguing that extensions of novel words on the basis of relations appears challenging for young children. In terms of the requirements for learning relational terms described by & Gentner & Boroditsky (2001), we are not suggesting that younger children are unable to make sense of events, but rather that they have difficulty to map words onto relational components of events.

In conclusion, the current study suggests that the use of just two exemplars can allow young children to break their tendency to map verbs onto an object-action interaction, and instead correctly map them onto an action only. It therefore supports the idea that young children can make use of structural alignment processes across multiple exemplars in order to bootstrap their understanding of word meaning up to a more adult like level. Under which conditions multiple exemplars are beneficial might vary from word type to word type. Maguire et al.'s study suggests that for intransitive verbs multiple exemplars seem to work best when they are identical. The present study and other studies (e.g. Waxman & Klibanoff, 2000) suggest that multiple exemplars may be maximally effective when they vary along one dimension, but not more dimensions.

CHAPTER FIVE

THE ROLE OF INHIBITION IN STRUCTURAL ALIGNMENT

Abstract

Gentner's structural alignment theory has been suggested as a way that young children are able to move beyond a reliance on perceptual features as a means for constructing categories. However, children may first need to inhibit a prepotent tendency to rely on perceptual similarity when doing so. The present study aimed to investigate this possibility by testing 3- to 5-year old children on their ability to make use of structural alignment in a noun extension task alongside a test of their inhibition ability. In addition, any developmental change in the effect of structural alignment and its relation to inhibition ability across the preschool period was investigated. Results showed that all age groups made use of structural alignment and that it helped 3- and 4-year-olds to perform above chance level. Furthermore, children's ability to make use of structural alignment was associated with their inhibition ability. These finding suggest that children are able to make use of structural alignment from as young as 3-years of age, but it is still providing benefits at age 5. In addition, children appear to need to inhibit a tendency to extend noun / category membership on the basis of shared perceptual features as a part of the structural alignment processes.

5.1. Introduction

When children begin to learn nouns, they also by extension begin to learn categories. But which objects fit into the same category and therefore have the same name? Objects that have the same name tend to look alike and at the same time tend to have the same function. But importantly, for adults objects and therefore categories are defined by their function. Adults will extend an object's name to other objects which share the same function regardless of the appearance of the objects (e.g. Miller & Johnson-Laird, 1976). For instance a sponge is a sponge, whether it is shaped like a block or like an apple.

This is not an understanding which is immediately present in young children. According to Clarke (1973) the form / structure of a word's referent determines children's early understanding of the word's meaning. This can be seen in the "shape bias" in noun learning: there is evidence that young children tend to extend an object's name to other objects which share the same shape as the original referent, rather than to objects which share the same function. For instance, Gentner (1978) showed children two objects which possessed different forms and functions and gave them novel names. When asked to name a new novel object which had the form of one of the objects and the function of the other, younger children labelled it on the basis of shared shape. The tendency to extend on the basis of shared function increased with age. Similar findings emerged from a study by Merriman, Scott, and Marazita (1993). They found that when younger children were simply shown a novel object and asked to extend its name, they extended it to an object with a shared shape, while older children extended on the basis of shared function. Further research by Smith, Jones, & Landau (1996) showed that young children will privilege perceptual features in general, not just shape. Three-year-olds were influenced by saliency of perceptual features in their extensions of novel nouns, but were not influenced by function. Indeed findings from Graham, Williams,

& Huber (1999) suggest that even when function is emphasised, shape rather than function may still form the basis for 3- and 5-year-olds noun extensions.

However, young children are capable of using features other then shape, such as function as a basis for their noun extensions. Under the right circumstances, for instance when allowed to experience the function for themselves, young children are able to use function as a basis for noun extension (e.g. Kemler Nelson, 1995; Kemler Nelson, 1999; Kemler Nelson, Russel, Duke, & Jones, 2000; Kemler Nelson, Frankenfield, Morris, & Blair, 2000, Booth, Waxman & Huang, 2005). This suggests that there might be an initial focus on perceptual features such as shape, but that this bias can be overcome. The present study investigates whether the success at overcoming the initial focus on perceptual features in noun extension / categorisation is related to children's inhibitory control ability.

One means that has been suggested to help to look beyond perceptual features such as shape is "structural alignment". According to the "structural alignment theory" proposed by Gentner and colleagues (e.g. Gentner, 2003) the act of comparison, even if initially prompted by noticing perceptual similarities between two objects, will highlight deeper relational commonalities such as a shared function (Gentner and Namy, 2006). This idea originally grew out of the literature on analogical comparison in adults. Gentner & Markman (1997) found that when adults were shown a picture in which a truck was towing a car and a picture in which a car was towing a boat and asked to indicate which object in the second picture matched the car in the first, results were strikingly different depending on whether they had been asked to compare the two pictures. Those in the non-comparison group chose the car in the second picture, i.e. the perceptual match, while those in the comparison group chose the boat, i.e. the relational / functional match. Therefore the act of comparing the two pictures and the resultant structural alignment highlighted to the participants the conceptual / relational similarities of the car in the first picture to the boat in the second picture and allowed them to select the correct match.

Structural alignment theory was subsequently extended to encompass children's word learning, in particular learning of object names. Children's early word extensions are typically based on perceptual similarities. This is particularly apparent in children's over-applications of names to similarly looking objects. It is not uncommon for children to start off calling all four-legged animals 'dog' or 'cat. Gentner & Namy (2006) suggest that children come to a deeper understanding of words by means of comparison processes. That is by comparing different referents of a word, children gain an enriched understanding of the word's meaning. This is based on the key ideas that words are invitations to compare and comparison highlights relational commonalities (Gentner & Namy, 2006). Children will subsequently extend object names on the basis of shared relational commonalities such as function rather than perceptual similarities.

Evidence for structural alignment processes in noun extensions comes from a study by Genter & Namy (1999). Four-year-old children were asked to extend a novel noun (e.g. a "blicket") from one object (a bicycle) to either an object that was perceptually dissimilar to the original referent, but shared the same base-level category (a skateboard), or to an object that was perceptually similar but differed in base-level category membership (eyeglasses). All objects were presented as picture cards and once presented they remained on the table. For adults base-level categories are made up of items which share the same function (e.g. a car, a bike, and a boat are all vehicles and they all function to transport people). When participants were shown only one exemplar of the noun (a bicycle) they extended it to the perceptual match (the eyeglasses). However, when they were shown two exemplars (a bicycle and a tricycle) for the same noun *blicket*, they instead extended the noun to the category match. And this was the case despite the fact that the two exemplars (bicycle and tricycle) were more perceptually similar to the perceptual match than the category match and thus provided twice as much perceptual evidence for selecting the perceptual match. The use of two exemplars with the same name allowed the participants to compare the objects and thus notice deeper relational commonalities. Consequently, the participants in the multiple exemplars group correctly extended the noun on the basis of shared base-level category membership.

Even though in the single exemplar condition of Genter & Namy (1999) participants saw the exemplar and the two possible choices for extension on the table at the same time, they did not engage in the same kind of comparative processes with the pictures on the table, as they did between the two exemplars in the multiple exemplar condition. This is because the children needed to hear the two object pictures labelled with the same noun in order to prompt these comparative processes, as they did in the multiple exemplar condition. At no point in the single exemplar condition did participants hear two objects labelled with the same noun. The adult participants in Gentner & Markman (1997) did not engage in the comparative processes and subsequent structural alignment which would lead them to correct extensions based on relational similarity until explicitly instructed to do so. For the child participants in Genter & Namy (1999) hearing the same label for the two objects had the same effect i.e. prompting the act of comparison between these two objects.

Further support for the benefits of structural alignment in word learning and in particular the idea that words are invitations to compare comes from Namy & Gentner (2002). In this study 4-year-olds would be presented with two objects (e.g., a bicycle and a tricycle), which were either given the same name (e.g., “blicket”) or two different names (e.g., “blicket” and “riffel”). When asked to ‘find another one’, the children chose a perceptual match over a category match when the two objects had been given different names. However, when they had been given the same name, participants chose the category match over the perceptual match.

Structural alignment processes have also been found to be beneficial in allowing preschool aged children to accurately extend other types of words than nouns that refer to objects, namly to novel part names, adjectives and verbs. Gentner, Lowenstein, and Hung (2007) found that children were more accurate in extending novel part names to other similar objects in comparison to dissimilar objects, as similarity aided structural alignment. In addition, having previously extended novel part names to similar objects improved accuracy when extending them to dissimilar objects. Waxman & Klibanoff (2000) demonstrated that accurate extension of novel adjectives was supported by the presentation of two exemplars which varied along only one dimension (base-level category membership of visual transparency). With regard to verb learning, a number of studies have demonstrated that presentation of multiple exemplars when introduced to a novel verb facilitates accurate extension of the verb in preschool aged children (Maguire, Hirsh-Pasek, Golinkoff, & Brandone, 2008; Childers, 2011; Chapter 4 of the current thesis).

As stated above, previous research suggests that children may initially extend nouns on the basis of perceptually similarities and later shift towards a more adult-like behaviour to extend nouns on the basis of relational commonalities such as function. The "shape bias" literature suggests that such a switch does not happen suddenly, but appears to be a gradual change (e.g. Gentner, 1978). That is, within a given experiment, the older children are, the more often they extend nouns on the basis of function rather than shape. Similarly, Experiment 1 of Chapter 2 in the current thesis found that children in the preschool period gradually shift away from using perceptual similarity as their basis for compound-noun extension to deeper relational aspects of compound-noun meaning (i.e. how the two objects are related to each other).

Such a gradual change in noun extensions could be linked to the development of executive function abilities, in particular the development of inhibition. Inhibition abilities include inhibiting prepotent responses, i.e. responses that an individual would naturally give in a given situation. It is possible that in order for children to make use of structural alignment processes and to look past striking perceptual similarities, they need to inhibit their natural focus on perceptual similarities. Focussing on perceptual similarities is a sensible approach and one which will have served children well during their early word learning when learning names for basic objects, because many objects which look the same are also called the same. But in order to take a new and more adult like approach to extending nouns on the basis of relational similarities, they would need to inhibit this earlier approach.

Inhibition is one of a number of executive function abilities, alongside attention switching abilities and working memory (Hughes, Graham, & Grayson, 2005). Children do not possess the same level of executive function abilities as adults. Instead, different abilities manifest at different ages and have been found to improve with age (Carlson, 2005; Garon, Bryson & Smith, 2008; Hughes & Ensor, 2011). Inhibition ability improves considerably between the ages of three and five years (Diamond, 1991; Carlson & Moses, 2001; Carlson, Moses, & Breton 2002; Carlson, Moses, & Claxton, 2004; Carlson, 2005; Jones, Rothbart, & Posner, 2003; Garon, Bryson, & Smith, 2008), i.e. around age 4, the age at which structural alignment has been shown to benefit children in noun extension tasks (e.g. Gentner & Namy, 1999; Namy & Gentner, 2002).

In the present study we aimed to investigate whether children’s ability to carry out structural alignment and the success at overcoming the initial focus on perceptual features in a noun extension / categorisation task might be related to their inhibition ability. Previous research into children's use of structural alignment and language processing has focussed on 4-year-old children. Given the development of inhibition abilities during the preschool years, we investigated structural alignment and its relation to inhibition abilities in a slightly wider age range, namely between the ages three and five years. In order to do this we replicated Namy & Gentner's (2002) structural-alignment-in-word-categorisation paradigm and assessed children's inhibition ability with the Grass / Snow task (Carlson & Moses, 2001). Based on findings that inhibition ability increases with increasing age (e.g. Carlson & Moses, 2001) and our suggestion that children may first need to inhibit a focus on perceptual similarities to engage in structural alignment we would predict that an association between inhibition ability and structural alignment exists. Additionally, if we found a correlation between structural alignment performance and inhibition ability, we wanted to assess whether this correlation was due to a development in inhibition ability alone or a development in overall executive function abilities. We therefore also tested children's working memory (another component of executive function), an ability that improves between ages 3 and 5 in self-ordered pointing tasks (Diamond, 1991, Ewing-Cobb et al, 2004; Garon, Bryson, & Smith, 2008). To this end we adapted the stationary boxes task used in Ewing-Cobb et al. (2004).

5.2. Method

5.2.1. Participants. 40 three-year-olds (mean age 41.6 months, *SD*= 3.3), 40 four-year-olds (mean age 53.9 months, *SD*= 3.6.) and 40 five-year-olds (mean age 65.4 months, *SD*= 3.5) participated in the experiment. Participants were recruited from nurseries and schools in the West Midlands area of the United Kingdom. Permission for them to participate was granted by either the head teacher or the owner of the nursery. Parental consent was obtained when requested by the head teacher / nursery owner. All participants were native monolingual speakers of English.

5.2.2. Design. The experiment had a between subjects experimental design. The independent variables were Numbers of exemplars (single vs. two) and Age group (3-years, 4-years, and 5-years). The dependant variable was number of correct generalisations of nouns to taxonomic category matches. A correlational study was carried out that compared structural alignment task performance in the multiple exemplar condition (henceforth referred to as SAM) to age (in months), working memory and inhibition ability.

5.2.3. Materials. Materials for the structural alignment task consisted of a set of laminated cards displaying pictures of everyday objects that children would be familiar with, e.g. a football or an orange. For a complete list see Appendix D. For the single exemplar condition 10 sets of 3 cards were used. For the multiple exemplar condition additional cards were added to represent the second exemplar resulting in 10 sets of 4 cards.

5.2.4. Procedure. Participants were randomly assigned to either the single exemplar or the multiple exemplar group.

Structural alignment task (single exemplar group): Participants were first introduced to the experimenter's puppet "Bear". They were told that Bear has special bear names for things which are different to the names we use. They were then told that they are going to hear some of Bear's special names for things. Participants received ten trials. In each trial, a single card displaying a cartoon style picture of a familiar object (e.g. an apple) was placed on the table in front of the participant. Below the original card two more cards were placed side by side. One was a picture of an object perceptually similar to the original object, but not taxonomically (= perceptual match), e.g. a balloon. The other was a picture of an object from the same taxonomic category, but perceptually dissimilar (= taxonomic match), e.g. a banana. Which side the perceptual and taxonomic matches occurred on was randomised across trials. Participants then heard Bear's special name for the original object and were asked which of the other two objects they thinks also shares that name. For instance the experimenter said "Bear calls this a blik (experimenter points to the apple with Bears hand). Which of these other two things would Bear also call a blik?" The child would then point at one of the cards

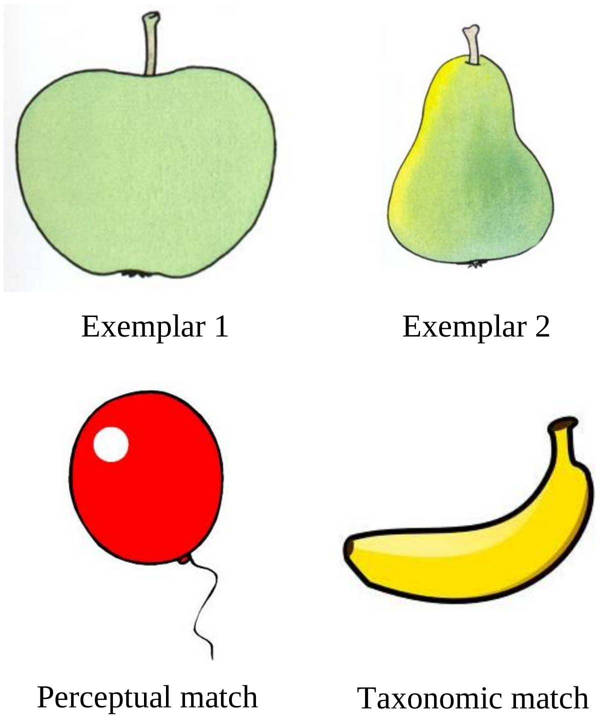


Figure 5.1. Example of structural alignment task. Exemplar 1 is seen in the single exemplar condition. Exemplar 1 and 2 are seen in the multiple exemplar condition.

(the taxonomic match, e.g. the banana, being the correct choice). See Figure 5.1 for an example (note: only Exemplar 1 is seen in this condition).

Structural alignment task (multiple exemplar group): The procedure for the participants in the multiple exemplar condition was very similar to that of the single exemplar condition, except that they were initially presented with two rather than one card. The two cards were placed side by side and were both from the same taxonomic category, e.g. an apple and a pear. This made one of the pictures to choose from at test (e.g. the balloon) an object that is perceptually similar to both of the original exemplar objects, but not taxonomically (perceptual match). The other test picture (e.g. the banana) showed an object which was from the same taxonomic category, but perceptually dissimilar to the original exemplar objects (taxonomic match). After the cards had been placed participants then heard Bear's special name for the original objects and were asked which of the other two objects the child thinks also shares that name, e.g. "Bear calls this a blik (experimenter points to the apple with bears hand) and this a blik (experimenter points to the pear with bears hand), which of these other two things would Bear also call a blik?" The child would then point at one of the cards (the taxonomic match, e.g. the banana, being the correct choice). See Figure 5.1 for an example.

Grass / Snow (inhibition ability task). Participants were told that they are going to play a game with the experimenter called the opposites game. They were then asked "what colour is grass?" and "what colour is snow?" Once they had answered correctly, a green piece of paper and a white piece of paper were placed side by side in front of the participant. Participants were told that because this is the opposites game when the experimenter says "grass" the participant is to point at the white piece of paper (points as they say this) and when the experimenter says "snow" the participant is to point to the green piece of paper (points as they say this). There were then four practice trials where the experimenter says "grass, snow, snow, grass" to ensure the participants understand the task. Once the participant had demonstrated that they could pass the practice trials they progressed onto the main task trials. The participant was then told that they should point as fast as possible when they hear the experimenter say one of the names. The participant received 17 trials. Order presented was: G, S, S, G, G, G, S, G, S, S, S, G, G, S, S, G, G (G = grass; S = snow). Following trial 8 participants were reminded of the rules of the game. There were an equal number of instances where the correct response changed and stayed the same, i.e. green then green, and green then white.

Stationary cups (working memory task). We adapted the stationary boxes task used by Ewing-Cobb et al. (1994), which in turn was based on the self-ordered pointing tasks used in Petrides & Milner (1982) and Diamond et al. (1997). The experimenter placed 9 opaque cups mouth down on the table in a 3x3 grid. Under these cups the experimenter placed one marble each, in full view of the participant. The cups were then covered with an opaque box. Each time the box was lifted, the participant got to pick one cup to look for a marble in. The cup was lifted and if a marble was in the chosen cup, the marble was removed, the cup placed back in its original location and the box placed back over the cups. The box remained on the cups for a ten second period between each choice. This was repeated until all marbles were found. Participants were told that they needed to find all the marbles in as few picks as possible.

5.3. Results

Effects of age and multiple exemplars on correct noun extension

Figure 5.2 displays the results of the structural alignment task. Extending the noun to the taxonomic match was considered a correct selection.

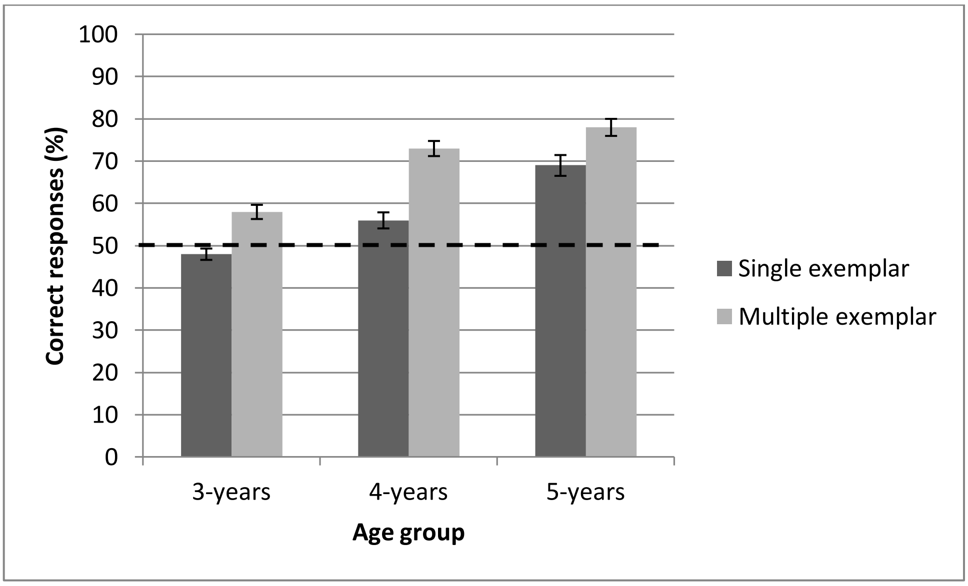


Figure 5.2. The effect of age group and number of exemplars on ability to extend noun to taxonomic match. Error bars represent standard error (50% line marks chance level).

The number of correct selections was analysed with a between-subjects ANOVA with Age group (3-years vs. 4-years vs. 5-years) and Number of exemplars (one vs. two) as fixed factors. Results indicated a significant main effect of Age group ($F(2, 114) = 14.3$, $p < .001$, partial $\eta^2 = .201$), showing that number of correct selections increased with age. Tukey HSD post-hoc tests indicated that number of correct selections differed significantly between all age groups ($p < .05$). There was also a significant main effect of Number of exemplars ($F(1, 114) = 14.7$, $p < .001$, partial $\eta^2 = .114$) showing that number of correct selections was higher for the multiple exemplar than the single exemplar condition. There was no significant interaction ($F(2, 114) = 0.7$, $p = .49$, partial $\eta^2 = .012$), suggesting that number of exemplars viewed did not affect the performance of the three age groups to a different degree.

In addition, we conducted planned comparisons of the number of correct selections against chance (5 out of 10 responses). In the single exemplar condition, only the 5-year-olds performed significantly above chance level ($t(19) = 3.9$, $p = .001$), three- and four-year-olds performed at chance level (3-years: $t(19) = -0.8$, $p = .464$; 4-years: $t(19) = 1.4$, $p = .172$). In the multiple exemplar condition, all three age groups made the correct selection significantly more often than would be expected by chance (3-years: $t(19) = 2.4$, $p = .028$, one tailed; 4-years: $t(19) = 6.2$, $p < .001$, one tailed; 5-years: $t(19) = 6.9$, $p < .001$).

Performance on inhibition task

Performance on the inhibition task for 3-year-olds was Mean = 11.9, SD = 2.7; for 4-year-olds was Mean = 13, SD = 2.8; for 5-year-olds was Mean = 13, SD = 2.

Performance on working memory task

Performance on the working memory task for 3-year-olds was Mean = 11, SD = 2.1; for 4-year-olds was Mean = 10.9, SD = 2.4 ; for 5-year-olds was Mean = 11.3, SD = 2.6.

Relationship between SAM and age, working memory and inhibition ability

For the relationship between the structural alignment task and working memory and inhibition ability, we focused on children's responses in the multiple exemplar condition (SAM) because this was the condition where participants could use comparison across the two exemplars to engage in structural alignment and we were interested in the role of inhibition in this. Figure 5.3 displays scatter plots of the relationship between the number of correct responses on the SAM task with age in months, number of correct responses on the working memory and inhibition tasks. As displayed in Table 5.1, SAM performance was positively and moderately correlated with both age and inhibition ability, but was not correlated with working memory. Age and inhibition ability were also positively correlated with each other, but not as strongly as each of them was correlated with SAM performance.

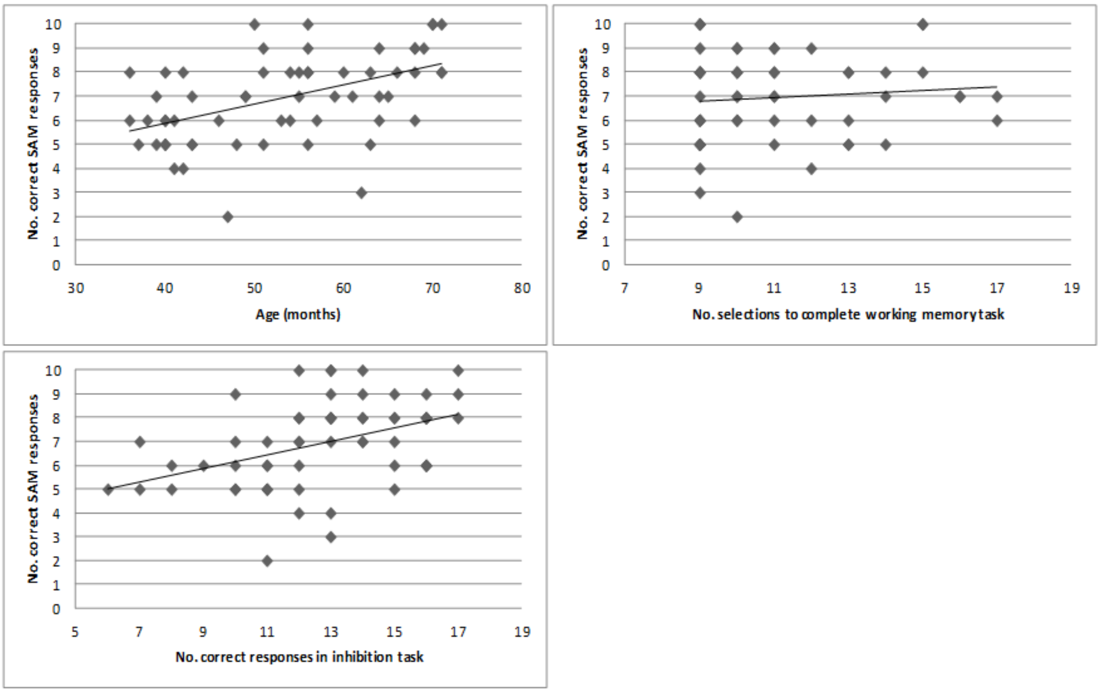


Figure 5.3. Scatterplots to show the relationship between SAM and age in months, working memory, and inhibition ability

Table 5.1: Intercorrelations between SAM performance and all potential predictor variables

	1	2	3
1. Structural alignment task (SAM)			
2. Age in months	.49**		
3. Memory task	.08	.16	
4. Inhibition task	.42**	.27*	-.003

*Significant at p < .05
** Significant at p < .001

Table 5.2: Hierarchical regression analysis predicting SAM performance (N = 60)

Step	Variables entered	Cumulative R^2	R^2 change	Beta
1	Age in months	.237 ($p < .001$)	.237 ($p < .001$)	0.486 ($p < .001$)
2	Age in months	.324 ($p < .001$)	.087 ($p <.05$)	0.4 ($p < .05$)
	Inhibition ability			0.307 ($p <.05$)

A regression analysis was carried out in order to examine whether both age and inhibition ability predicted correct selections on the SAM task. Variables were entered in two steps in order to first examine the effect of age in months, prior to our particular variable of interest: inhibition ability (as assessed by the Grass / snow task). Table 5.2 shows that age in months was a significant predictor in Step1. At Step 2 both age in months and inhibition ability were significant predictors of SAM performance. Age in months accounted for 23.7% of the variance in SAM performance. With the addition of inhibition ability, 32.4 % of the variance in SAM performance was accounted for. Significantly greater performance was explained when inhibition ability was introduced to the model. Therefore both older children and those with better inhibition ability performed better on the SAM task.

Relationship between SAS and age, working memory, and inhibition ability

As a further point of interest we looked at the relationship between responses in the single exemplar condition of the structural alignment task (SAS) and working memory and inhibition. Figure 5.4 displays scatter plots of these relationships. As shown in Table 5.3, SAS performance was positively and moderately correlated with both age and inhibition ability,

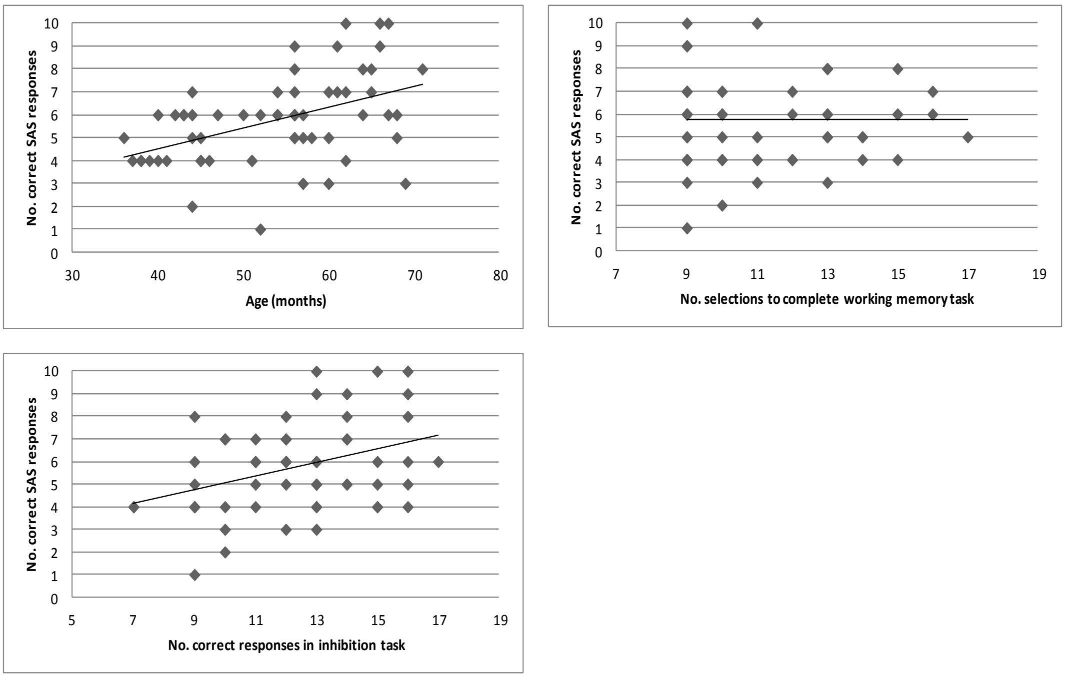


Figure 5.4. Scatterplots to show the relationship between SAS and age in months, working memory, and inhibition ability

but not with working memory. We therefore carried out a regression analysis in the same manner as before, entering age in months at step 1 of the analysis and adding inhibition ability in at step 2. As shown in Table 5.4 age in months was a significant predictor at step 1, and both age in months and inhibition ability were significant predictors at step 2. Age in months accounted for 21.3% of the variance in SAS performance. With the addition of inhibition ability 31.8% of the variance in SAS performance was accounted for. Again, introducing inhibition ability into the model allowed significantly greater performance on the structural alignment task to be explained.

Table 5.3 Intercorrelations between SAS performance and all potential predictor variables

	1	2	3
1. Structural alignment task (SAS)			
2. Age in months	.46**		
3. Memory task	00	-.01	
4. Inhibition task	.37*	.11	.07

* Significant at $p < .05$
** Significant at $p < .001$

Table 5.4 Hierarchical regression analysis predicting SAS performance (N = 60)

Step	Variables entered	Cumulative R^2	R^2 change	Beta
1	Age in months	.213 ($p < .001$)	.213 ($p < .001$)	0.462 ($p < .001$)
2	Age in months	.318 ($p < .001$)	.105 ($p <.05$)	0.427 ($p < .001$)
	Inhibition ability			0.326 ($p < .05$)

5.4. Discussion

The current study aimed to determine whether children's ability to carry out structural alignment and to overcome the initial focus on perceptual features in a noun extension task is related to their inhibition ability. In addition, we investigated any developmental changes in structural alignment success over the ages 3- to 5-years and its relation to inhibition ability.

We found that children in the 3- and 4-year-old age groups were not able to make correct noun extensions more often than would be expected by chance when they viewed only one exemplar. However, having viewed two exemplars and therefore having had the opportunity for structural alignment, both of these age-groups were able to do so. Five-year-olds' performance also improved when seeing two exemplars. However, they performed above chance level with only a single exemplar. Our findings therefore confirm those of Gentner & Namy (1999) and expand upon them by showing that children as young as 3-years can engage in structural alignment and that it still provides some benefit for older children.

We also found a positive relationship between the ability to make use of structural alignment processes and children's inhibition ability. This relationship cannot be explained by a general improvement in children's cognitive ability with age because it was independent of a relationship with age; a model including inhibition ability was able to explain almost 10% more of the variation in children's responding, than a model featuring only age in months. Also, working memory ability was not found to be associated with structural alignment ability. This suggests that children's development of inhibition ability does indeed contribute to their ability to make use of structural alignment processes, although the additional association with age shows that this is not the only contributing factor.

Performance on the single exemplar condition of the structural alignment task was also found to be associated with inhibition ability, although not as strongly as it was associated with performance on the multiple exemplar condition. Furthermore, a model including inhibition ability was again able to explain around 10% more of the variation in children's responding, than a model featuring only age in months. This suggests that children also need to inhibit their tendency to focus on perceptual features as a basis for noun meaning / category membership in the single exemplar condition. Participants in the single exemplar condition also need to inhibit the prepotent tendency to make extensions on the basis of shared perceptual features. Inhibition may not be as important a factor in the single exemplar condition as participants only have half as much evidence for selecting the perceptual match i.e. one, rather than two exemplars that are more perceptually similar to the perceptual match than the taxonomic match. However this finding does suggest that inhibition ability may not only be important for carrying out structural alignment, but also for noun extension in general.

It therefore appears that in order to make use of this structural alignment process, which bootstraps children up to more mature noun extensions, young children may indeed need to make use of inhibition. Because the process of structural alignment is often prompted by noticing perceptual similarities (Gentner & Namy, 2006), children may first need to inhibit the prepotent response to extend a novel noun to an object which is perceptually similar to the original referent. If perceptual similarities are the first thing children notice then they could just use this as the basis for their extensions. After all, extending object names on the basis of perceptual similarity is a legitimate technique which may have served children well in initial language learning. In order to make adult-like extensions, they appear to need to inhibit this early word leaning strategy.

The idea that perceptual similarity may be children's first port of call when extending nouns, but with age extensions are based more and more on relational similarities, such as function is in accordance with the shape bias literature (e.g. Gentner, 1978; Merriman, Scott,

& Marazita, 1993; Smith, et al., 1996; Graham, Williams, & Huber, 1999) . Based on our findings it is possible that in order to extend nouns on the basis of function, children first need to inhibit the prepotent tendency to make extensions on the basis of perceptual similarities, such as shape. As children's inhibition ability increases with increasing age (Diamond, 1991; Carlson & Moses, 2001; Carlson et al, 2002; Carlson, Moses, & Claxton, 2004; Carlson, 2005; Jones, Rothbart, & Posner, 2003; Garon, Bryson, & Smith, 2008), this may help to explain why the shape bias is overcome with age.

Interestingly, children's performance in the structural alignment task was not associated with their performance in the working memory task. This suggests that improving ability to make use of structural alignment is not associated with improvement in overall executive function ability, but rather more specifically with improvement in inhibition.

Our findings also speak to the suggestion of a general relational shift in word learning, as suggested in Chapter 2. There it is proposed that children undergo a developmental focus shift during word learning from non-relational features of a scene / object (e.g. shape / other perceptual features) towards relational features (e.g. function). Further research should investigate whether the relational shift is linked to children's inhibition ability as well. In order for children to focus on the relational component of a scene / object when learning a new word, they might first need to inhibit a prepotent tendency to focus on the non-relational features of an object or scene.

The importance of inhibition ability for the ability to switch the focus away from perceptual features has also been suggested for other tasks that require comparison in order to highlight relational commonalities, namely analogical reasoning tasks. It has been pointed out that to select a relational match over a more salient featural match in an analogical reasoning task, responses in line with the featural match must be inhibited (Morrison et al., 2004;

Viskontas et al., 2004; cited in Rickland, Morrison, & Holyoak, 2006). For instance, Rickland and colleagues (2006) found in an analogical reasoning study with children that the impact of featural distractions diminished as the age of the children increased. The authors suggested that these findings can be explained in terms of maturation of inhibition ability with age. Furthermore, using a computational model of analogical reasoning, Morrison, Doumas, and Richland (2011) found that an improved ability to deal with featural distracters could be explained by changes in inhibitory ability. Furthermore, it has been found that individuals with damage to the prefrontal cortex (a brain area associated with inhibition) demonstrate difficulties with ignoring more salient choices in order to select relational matches in analogical reasoning tasks (Waltz, Lau, Grewal, & Holyoak, 2000; Morrison et al., 2004; Krawczyk et al., 2008). Together with our findings, there is a growing consensus that in order to arrive at deeper conceptual insights, more salient perceptual / featural distracters must be inhibited.

Finally, while we have demonstrated that children as young as 3-years of age are capable of benefiting from multiple exemplars and subsequent structural alignment in their category learning, other research has shown that there are limits to the benefits that this youngest age-group can derive. Gentner, Anggoro, & Klibanoff (2011) found that 4- and 5-year-old children were able to correctly extend relational categories (i.e. categories defined by their relationship to other items, e.g. a hutch and a rabbit as an exemplar of *home for*) after seeing two exemplars. Three-year-olds on the other hand were not. They required progressive alignment in which they were shown high similarity exemplar pairs followed by the same low similarity exemplar pairs that older children had been successful with, in order to be successful themselves. For example they would be shown a knife and a melon paired with a knife and a kiwi followed by an axe and a tree paired with a saw and a log as examples of *for* *cutting*. Note that all age groups mentioned needed to hear relational language to be successful (e.g. “this knife is the *klib for the kiwi*”, rather than “this knife *goes with the kiwi*”). The difference between our results and those of Gentner et al. (2011) are likely due to the greater challenge of relational categories. Comparison across two exemplars appears to be enough to allow 3-year-olds to make correct noun category extensions, but not to correctly extend relational category membership.

In conclusion, we have aimed to discover whether structural alignment is a gradually emerging process in children’s noun / category learning and if the ability to make use of these processes is linked to inhibition ability. We have found that structural alignment ability is present from 3-years of age, and appears to provide benefit to children throughout the pre-school years. Furthermore, inhibition ability appears to be important for structural alignment and potentially for noun extension in general.

CHAPTER SIX

DO CHILDREN WITH AUTISM BENEFIT FROM STRUCTURAL ALIGNMENT IN THEIR CATEGORY CONSTRUCTION?

Abstract

It has long been suggested that individuals with autism may struggle with construction of categories. While research has shown that they are capable of constructing categories, it has also been indicated that they may do so via different processes to those used by typically developing individuals. Structural alignment has been suggested by Gentner and colleagues as a means via which young children shift towards more adult-like category construction. In the current study we tested whether individuals with autism also engage in structural alignment when constructing categories. This was achieved by asking both autistic and typically developing children to extend novel nouns to objects that were either a perceptual or conceptual match to a single exemplar or multiple exemplars. Results demonstrated that, unlike typically developing participants, those with autism gained no benefit from seeing multiple exemplars of the category. Thus they did not appear to engage in structural alignment in their formation of categories. This finding adds to the consensus that individuals with autism construct categories via different processes to typically developing individuals. Weak central coherence as a possible explanation is discussed.

6.1. Introduction

The formation of categories is an important part of developing an understanding of the world. Having formed categories allows us to identify on sight what things are, what they might do, and what we may be able to use them for, amongst other things. Children show an understanding of categories from early on and this understanding develops during the preschool period (e.g. Clark, 1973; Nelson, 1973; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Mandler & Bauer, 1988). It was initially suggested by Tager-Flusber (1985a) that people with autism may struggle with categorisation (Menyuk, 1978; Fay & Schuler, 1980; Jackendoff, 1983) and that this may be linked to their difficulty in drawing information together into a coherent whole (see central coherence theory; Frith, 1989; Frith & Happe, 1994) and integrating new information with stored representations (Rimland, 1964; Hermelin, 1978).

Early research on individuals with autisms' categorisation ability produced mixed results. Some research suggested that people with autism can not form categories (Schuler & Bormann, 1982, cited in Tager-Flusber, 1985a), while other studies suggest that they can (Tager-Flusber, 1985a; Tager-Flusber, 1985b; Ungerer & Sigman, 1987). Tager-Flusber (1985a) demonstrated that after being shown a picture of an object, high-functioning children with autism were able to select a picture which belonged to the same category. Similarly, Tager-Flusber (1985b) found that children with autism proved as successful as age-matched controls at both confirming if an object belonged to a named category and selecting object pictures that belonged to a category from a selection provided. Ungerer & Sigman (1987) extended these findings to preschool age children with autism, demonstrating that they were also able to sort objects into categories based on perceptual similarity and function at a level not dissimilar from typically developing children.

A closer look at this early research purporting to demonstrate individuals with autisms' ability to form categories shows that it relied primarily on match to samples tasks where one of the choices always looked more like the target than the other. This means that most categories could be formed through the grouping of objects that share perceptual features. For instance, while Ungerer & Sigman (1987) claimed to test the existence of categories based on shared function, the different function categories used were extremely dissimilar from each other perceptually e.g. animals vs. fruit. Participants only had to sort shapes between two functional categories at a time, so results could have been obtained by participants simply matching a series of objects that looked the most like each other. Thus, they might have macthed a horse with a lion because it looks a lot more like a lion than a banana does. This means that individuals with autism might be able to sort objects by perceptual features, but not by function. This was confirmed by a study by Shulman, Yirmiya, & Greenbaum (1995) who found that low functioning individuals with autism were able to sort geometric shapes along one or two perceptual dimensions. However when required to sort representational objects (e.g. vehicles, tools), the same individuals performed worse than both typically developing individuals and intellectually impaired individuals. The authors suggest that this is due to sorting representational objects involving internally manipulating information and the requirement to understand how elements are interrelated.

Further research into categorisation in individuals with autism found differences in event-related potential activity between autistic and typical children during a categorisation task (Dunn, Vaughan, Kreuzer, & Kurtzburg, 1999). Participants were required to raise their index finger following auditory presentation of an animal name, after an expectancy that they would hear an animal name had been set up. Autistic participants were slower to respond to animal names and produced more errors (though not significantly in the case of errors). In addition, event-related potential activity to animal or non-animal names differed only for typically developing participants, not for autistic participants. The authors conclude that children with autism differed from typically developing children in how semantic information was neurally processed. That is, expecting in advance for words to be from a particular category, i.e. animals, did not result in selective activation of words from this category over words from other categories in the autism group.

These early studies tended to test categories participants have already learned rather than investigating how they learn them. In contrast, later research tended to accept that individuals with autism can form categories, and instead investigated whether the processes by which they form them differ from those of typically developing individuals. Findings by Klinger and Dawson (2001) suggest that individuals with autism may not form prototypes of categories (see also Plaisted, 2000). A prototype is an internal representation of a best example of a given category. It is distinct from a simple exemplar of a category in that an exemplar can vary in how typical it is of a given category, whereas a prototype represents the most typical example. This prototype is constructed from the individuals' experience with category members by calculating the average of these previously encountered examples (Klinger and Dawson, 2001). Therefore when individuals with autism encounter a potential new instance of a given category they will not have a stored representation of a prototype to compare it to. The authors found that individuals with autism were capable of learning categories of novel animals when a rule existed which defined the category. However when no such rule existed and participants were instead required to rely on the formation of a prototype they were no longer able to learn the new category. Therefore individuals with autism may instead be relying on a rule-based approach to constructing categories. However it should be noted that the rules used in the tasks were very simple and based on only to a single feature of the animals. Individuals with autism may experience greater difficulty when required to integrate multiple rules / pieces of information in order to construct a category. This conclusion is also supported by a study by Minshew, Meyer, and Goldstein (2002). According to Gastgeb, Srauss, & Minshew (2006), they found that while high-functioning autistic people can categorise information on the basis of rules, when they need to abstract concepts from complex information, they do not perform as well as controls.

In contrast to Klinger and Dawson (2001) and Plaisted (2000), Molesworth, Bowler, and Hampton (2005) reported that individuals with autism can form prototypes. In two recognition memory tasks a group of high functioning individuals with autism demonstrated a prototype effect at a level that did not differ from typical age-matched controls. That is, when required to identify pictures from a particular category (e.g. animals) that they had seen before, both groups selected (incorrectly) prototypes and pictures that were highly familiar to the prototype more often than the actual pictures they had seen before. Molesworth et al. (2005) suggest a range of possible reasons for the disparity between their findings and those of Klinger & Dawson (2001) regarding the presence of a prototype effect in autism. For instance, in Klinger & Dawson's study participants had to select category members, while in Molesworth et al.'s they had to recognise whether they had seen a picture before, perhaps suggesting intact recognition memory for categories, but impaired selection processes. In addition, Klinger & Dawson's findings might be the result of a developmental delay.

Further research aimed to delve deeper into the categorisation abilities of individuals with autism. In other words, studies investigated not so much whether they can categorise, but how their categorisation ability differs from that of typically developing individuals. Gastgeb, Strauss, & Minshew's (2006) results suggest that autistic people can successfully categorise typical or simple objects but struggle when dealing with non typical or complex objects. The authors suggest that their findings may indicate differences in a set of underlying processes that are more strongly brought into play when individuals with autism are required to process non-typical examples of categories. Individuals with autism might experience problems with considering multiple features, comparing exemplars to stored prototypes (see literature above), and comparing spatial information where only subtle differences are present.

Further support for differing categorisation abilities were provided by Bott, Brock, Brockdorff, Boucher, & Lamberts (2006) who presented evidence that high-functioning individuals with autism differ from controls in their learning of categories. They reported that individuals with autism took longer to learn categories made up of rectangles within a height and width range, and report a trend that their representations of the stimuli tended to be based on fewer dimensions than those of controls. In addition, Soulieres, Mottron, Saumier, & Larochelle (2007) found that, unlike typical participants, when required to decide whether geometric shapes were the same or different, individuals with autisms' performance was not affected by whether the two shapes were from the same category. This therefore suggests that individuals with autism are not influenced by categorical knowledge in their discriminations. The authors argue that this finding highlights a decreased top-down influence of categories in individuals with autism, leaving low-level perceptual processes more in charge of discrimination. Furthermore, when required to learn two categories made up of imaginary animals, Soulieres, Mottron, Giguere, & Larochelle (2011) found that individuals with autism showed identical levels of categorisation accuracy to control participants, but were slower to reach this level. The authors suggest that this finding represents those with autism requiring more time with the materials that they are to catogorise in order to do so successfully, most likely as a result of the decreased influence of top-down processes (rules) suggested by Soulieres et al. (2007).

It appears that research into individuals with autism's category learning abilities has produced mixed and sometimes contradictory results. The overall picture that has emerged seems to be that, while people with autism do indeed construct categories, there are substantial differences between the category construction of autistic and typically developing individuals. They may take longer to learn categories. They tend to have difficulties when required to categorise representational objects (e.g. vehicles, tools) and those that are non-simple / complex or atypical, rather than simple perceptually similar objects (e.g. geometric shapes). The influence of categories may not result in the same pattern of activation in the brains of individuals with autism. Tied to this, categories may not exert the same top-down influence in those with autism. Furthermore, they may not form prototypes of categories to use in identifying potential members of a given category, but rather rely on a set of necessary and sufficient rules.

An important process by which typically developing children have been shown to move beyond simple categories based on perceptual similarities to more complex categories based on causal or functional similarities is that of structural alignment (Gentner & Namy, 1999). In Gentner & Namy (1999) a group of 4-year-olds was shown an object (e.g. a bicycle) which was labelled with a nonsense word and asked to extend that word to either an object that was perceptually similar but from a different taxonomic category (e.g. a pair of spectacles) or an object that was from the same category but was perceptually dissimilar (e.g. a skateboard). A second group of 4-year-olds was required to make the same selection but were shown two standards instead of one. These were from the same taxonomic category, were both more perceptually similar to the perceptual choice than the taxonomic choice (e.g. a bicycle and a tricycle) and were given the same label. It was found that the group who saw two standards were more likely to make the taxonomic choice than the group who saw only one. These findings suggest that 4-year-old children are able to look past more obvious perceptual similarities of objects and notice less obvious functional and conceptual links by comparing and noticing the perceptual similarities between the objects when those share the same name or are of the same kind. In this way structural alignment is a process by which children learn to form higher level categories based on conceptual and functional similarities rather than on more basic perceptual similarities.

There is reason to believe that structural alignment may be a process that people with autism do not engage in when building their categories. Firstly, structural alignment involves noticing perceptual similarities which in turn highlight relational commonalities. Bogdashina (2005) suggests that individuals with autism may have difficulty transitioning from sensory patterns which can be considered more concrete and literal to the more abstract forming of concepts and an understanding of function. She further suggests that they may have difficulty in determining which stimuli are relevant and should therefore be attended to. In line with the latter suggestion, Lovaas and Schreibman (1971) demonstrated that children with autism display stimulus over-selectivity, attending to only one of several relevant cues during learning. Once they had been trained to respond to a combined stimulus, consisting of both a visual and auditory component, typically developing children were able to respond to each component feature separately. Children with autism on the other hand responded only to one of the component features. Murray (1992) supports this idea of selective attention, suggesting that children with autism might display a very narrow attentional focus, with only certain features being perceived as being related while all other features outside of that narrow focus are ignored.

Secondly, structural alignment requires the comparison of two objects. The weak central coherence theory (Frith, 1989; Frith & Happe, 1994; Happe, 1999) proposed as a means of explaining the pattern of relative strengths and weaknesses in autism, suggests that the kind of comparative process required in structural alignment will prove difficult for those with autism. It claims that the learning of people with autism is often impaired by difficulties in identifying relationships between pieces of information, distinguishing between relevant and irrelevant information, and noticing central patterns and themes (Frith, 1989). These are all abilities required by structural alignment. Furthermore, the finding that individuals with autism may have difficulty constructing prototypes (e.g. Plaisted, 2000; Klinger & Dawson, 2001) might mean that they are not using internal representations of objects to guide their categorisation, which would lead to difficulties with structural alignment as it involves comparing representations of objects. This is especially true when encountering new potential instances of a category that would necessitate comparing a representation of this new object to the internal representation of a category held by the individual, i.e. their prototype. Structural alignment has also been suggested to strengthen children's ability to generalise insights into relations that may exist between objects to other objects and situations (Gentner & Namy, 2006), and generalisation beyond initial learning experiences is an area that individuals with autism are known to have difficulty with.

The current study aims to investigate the ability of individuals with autism to engage in structural alignment in their construction of object categories. This will be achieved by replicating the procedure of Gentner & Namy (1999) with individuals with autism, to determine whether viewing multiple exemplars of a noun category and the subsequent structural alignment will aid their category construction. Assessing people with autism on this task will add to what we understand about how they construct object categories. If they were found to be unable to perform structural alignment then it supports the idea that people with autism have difficulty in identifying relationships between pieces of information and, together with their inability to form prototypes (e.g. Klinger & Dawson, 2001), supports the idea that they do not form categories in the same way as normally developing individuals. If they were found to be able to perform structural alignment then it suggests that they are making use of processes used by normally developing individuals in their formation of categories, and that they can draw together information in this way and use perceptual information to infer a conceptual relationship. This would speak against the suggestion of the weak central coherence theory of autism (Frith, 1989; Frith & Happe, 1994) that individuals with autism are unable to draw together pieces of information in order to construct higher level meaning.

Individuals with autism have been suggested to be impaired in executive functions, including prepotent inhibition (e.g. Hill, 2004). It was found in Chapter 5 of the current thesis that inhibition ability is associated with ability to carry out structural alignment in the noun extension task used here. We wanted to ensure that any differences in ability to carry out structural alignment were not simply the result of differing executive function abilities between the two groups. We therefore also assessed participant’s performance on two tasks that measured inhibition ability: Grass / Snow and Knock /Tap (Carlson & Moses, 2001). Inhibition in these tasks involves preventing oneself from doing what comes naturally and instead acting in accordance with a rule. For instance, in the case of the Grass / Snow task, the experimenter says “grass”, while the participant is required to point to a white piece of paper rather than a green piece. The latter would be the natural response because grass is green. If results indicate that differences in the structural alignment task might be due to differences in inhibition abilities, then it is important to make sure that they are not due to differences in general executive function abilities. We therefore tested the participants also on a test of working memory.

6.2. Method

6.2.1. Participants. We tested two groups of participants. The first group consisted of participants diagnosed with an autism spectrum disorder (ASD). Those were recruited via a public advertising campaign and through various UK-based autism charities. The presence of an autism spectrum disorder was confirmed via administration of module 3 of the Autism Diagnostic Observational Schedule (ADOS; Lord et al., 2000). The ASD group consisted of 13 participants, however 3 were removed from the sample for having a verbal mental age (VMA) below the age necessary to pass the experimental task based on previous research (3-years; Chapter 5). This left 10 participants with a mean chronological age of 63 months (SD = 6.5, 8 males).

The second group was a comparison group of 10 typically developing children, recruited via the University of Birmingham Infant and Child laboratory database. Participants from the two groups were individually matched on VMA, determined by the mean of their score on the receptive and expressive language sub-scales of the Mullen Scales of Early learning (Mullen, 1995). Each participant in the ASD group was individually matched to a participant in the typical group with a VMA score within 6 months. The VMA scores of the two groups (typical group: mean 53 months, range 39 to 63; ASD: 52 months, range 40 to 68) did not significantly differ ($t(19) = -0.3$, $p = .787$). This resulted in participants in the typical group with a mean chronological age of 53 months (SD = 5.6, 8 males). Both groups consisted of 8 males and 2 females and all participants were native speakers of English. See Table 6.1 for a summary of demographic information for the two groups.

6.2.2. Design. The structural alignment experiment had a mixed experimental design. The between subjects independent variables was Participant group (ASD vs. Typical) and the within subjects independent variable was Number of exemplars (Single vs. Multiple). The

Table 6.1: Participant demographics summary (means / standard deviations)

Group	Chronological Age (months)*	Verbal Mental Age	Gender M / F	ADOS Score
ASD	63.3 (6.5)	52.3 (8.9)	8 / 2	10.9 (2.8)
Typical	51.2 (6.8)	53.3 (7.4)	8 / 2	NA

*Significant difference between groups at p <.05

dependant variable was number of correct extensions of nouns to taxonomic category matches.

6.2.3. Materials. Materials for the structural alignment task consisted of two sets of laminated cards that displayed pictures of everyday objects that children would be familiar with, e.g. a football. There were 10 sets of 3 cards for single exemplar trials and 10 sets of 4 cards for multiple exemplar trials. Different card sets and therefore completely different pictures were used for the single and multiple exemplar trials. The card sets used for the multiple exemplar condition were identical to those used in Chapter 5. For a complete list see Appendix D and E.

6.2.4. Procedure. Structural alignment task: After being seated opposite the experimenter, the participant was first of all introduced to the experimenter's puppet "Bear". They were told that Bear has special bear names for things which are different to the names we use and that they are going to hear some of Bear's special names for things. Participants received 20 trials, first 10 single exemplar trials and then 10 multiple exemplar trials. The arrangement of the trials (single exemplar first followed by multiple exemplar) allowed us to first of all assess participants category extensions without the potential benefit of being able to engage in structural alignment, then to see any improvements that the opportunity to engage in structural alignment through viewing multiple exemplars would provide. The single exemplar trials consisted of the participant being shown a single card displaying a cartoon style picture of a familiar object, which is placed on the table in front of them e.g. a clock.

They also see, placed side by side, below the original card two more cards. One is a picture of an object that is perceptually similar to the original object, but not taxonomically (perceptual match), e.g. a wheel. The other is a picture of an object which is from the same taxonomic category, but is perceptually dissimilar (taxonomic match), e.g. a square faced wrist watch. Which side the perceptual and taxonomic matches occurred on was randomised across trials. Participants then heard Bear's special name for the original object and were asked which of the other two objects the child thinks also shares that name, e.g. "Bear calls this a blik (experimenter points to the clock with bears hand), which of these other two things would Bear also call a blik?" The child would then point at one of the cards (the taxonomic match being the correct choice, e.g. the square faced watch).

The multiple exemplar trials consisted of participants being initially shown two cards, placed side by side, each displaying a cartoon style picture of a familiar object. These cards were both from the same taxonomic category, e.g. a bicycle and a tricycle. They also saw, placed side by side, below the original cards, two more cards. One was a picture of an object that is perceptually similar to both of the original objects, but not taxonomically (perceptual match), e.g. a pair of glasses. The other was a picture of an object which was from the same taxonomic category, but was perceptually dissimilar to the original objects (taxonomic match), e.g. a skateboard. Which side the perceptual and taxonomic matches occurred on was randomised across trials. Participants then heard Bear's special name for the original objects and were asked which of the other two objects the child thinks also shares that name, e.g. "Bear calls this a blik (experimenter points to the bicycle with bears hand) and this a blik

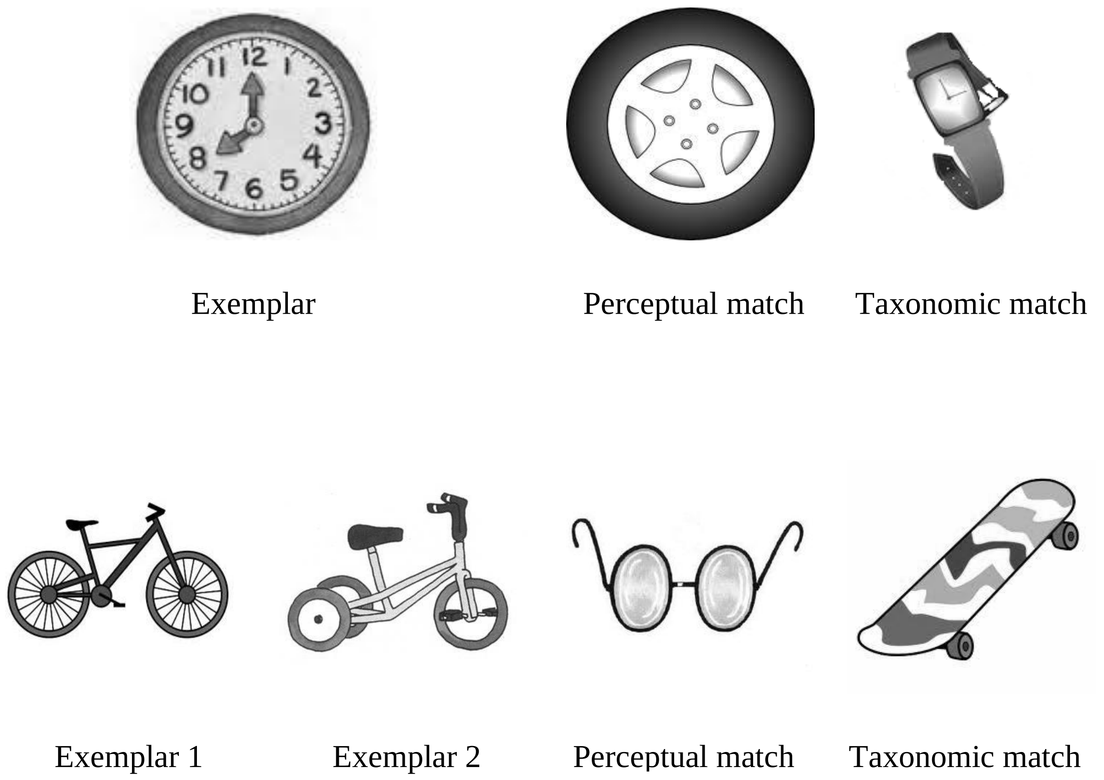


Figure 6.1. Example stimuli for structural alignment task. The first row displays a single exemplar trial. The second row displays a multiple exemplar trial.

(experimenter points to the tricycle with bears hand), which of these other two things would Bear also call a blik?" The child would then point at one of the cards (the taxonomic match again being the correct choice, e.g. the skateboard). See Figure 6.1 for an example of single and multiple exemplar trials.

Grass / Snow (inhibition task). Participants were told that they were going to play a game with the experimenter called the opposites game. They were then asked to tell the experimenter what colour grass is and what colour snow is. After the participant had answered, a green piece of paper and a white piece of paper were placed side by side in front of them. Participants were told that because this is the opposites game when the experimenter says grass they should point at the white piece of paper (experimenter pointed as he said this) and when the experimenter says snow they should point to the green piece of paper (the experimenter again pointed as he said this). Participants took part in two practice trials where the experimenter said grass, snow, snow, grass to ensure the participants understand the task. Only when participants had successfully completed the practice trial did they proceed onto the main trials. The participant was then told that they should point as fast as possible when they hear the experimenter say one of the names. The participant then received 17 test trials. There were an equal number of instances where the correct response changes and stays the same, e.g. green then white, and green then green. Order of correct response for trials was: W, G, G, W, W, W, G, W, G, G, G, W, W, G, G, W, W (W = white paper; G = green paper).

Knock / Tap (inhibition task). Participants were told that they were going to play another opposites game with the experimenter. The experimenter knocked on the table with his right hand and instructed the participant to do the same. The experimenter then tapped the palm of his right hand on the table and instructed the participant to do the same. The experimenter then tapped his hand on the table again. After the participant had copied the action they were told to "do the other one". As the participant knocked on the table while the experimenter tapped on it they were told "that's right, when I do this, you do that". The experimenter then changed to knocking and told the participant to do the other one. Again when the participant was tapping while the experimenter was knocking they were told "that's right, when I do this, you do that." The experimenter than knocked on the table and asked "what do you do?" When the participants tapped on the table they were praised. The experimenter than tapped on the table and asked "what do you do?" When the participants knocked on the table they were praised. This demonstration was then repeated, and the whole explanation repeated if the participant was unable to perform the opposite actions to the experimenter. Again, only when participants had successfully completed the practice trial, did they proceed onto the main trials. The participant was then told “now the trick is you have to do it as fast as you can”. The experimenter then presented 17 test trials. A correct response was scored when the participant made the opposite action to the experimenter, e.g. knocking when the experimenter tapped. There were an equal number of instances where the correct response changes and stays the same, e.g. knock then tap, and knock then knock. Order of correct responses was: K, T, T, K, K, K, T, K, T, T, T, K, K, T, T, K, K (T = tap, K = knock).

Stationary cups (memory task). Nine opaque cups were placed mouth down on a table in a 3x3 grid in full view of the participant. Into each of these cups the experimenter placed one marble. The cups were then covered with an opaque box. Each time the box was lifted participants were allowed to choose one cup to look for a marble under it. After it had been determined if there was a marble in the chosen cup, the marble was removed, the cup was placed back in its original location and the box was placed back over the cups. The box remained on the cups for a ten second period between each choice. Participants were told that they needed to find all of the marbles in as few picks as possible.

6.3. Results

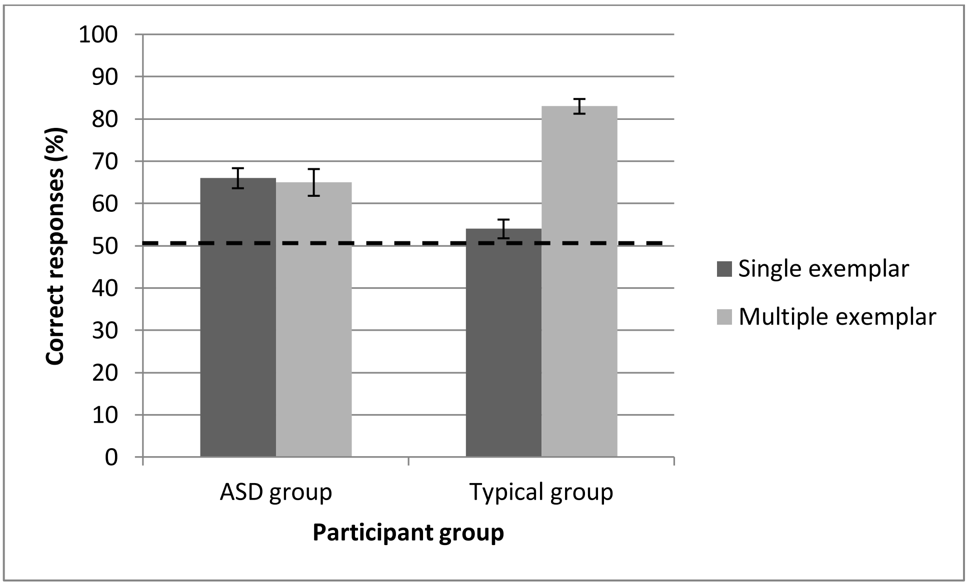


Figure 6.2. The effect of age group and number of exemplars on ability to extend nouns to taxonomic match (50% line marks chance level). Error bars represent standard error.

Structural alignment task

Figure 6.2 displays the results of the structural alignment task. Selecting the taxonomic match counted as the correct selection. The number of correct selections was analysed with a mixed plot ANOVA with Participant Group as a between subjects factor and Number of Exemplars as a within subjects factor. The test indicated a significant main effect of Number of Exemplars ($F(1, 18) = 10.7$, $p = .004$, partial $\eta^2 = .373$), indicating that more correct responses were produced after viewing multiple exemplars. There was a non-significant main effect of Participant Group ($F(1, 18) = 0.3$, $p = .57$, partial $\eta^2 = .018$), however the interaction between Participant Group and Number of Exemplars was significant ($F(1, 18) = 12.3$, p = .003, partial $\eta^2 = .406$) indicating a greater benefit of seeing multiple exemplars in the typical group. Follow-up t-tests showed that for the ASD group there was no significant difference between the multiple and single exemplar conditions ($t(9) = 0.145$, p =

.888). For the typical group, participants were found to make correct selections significantly more often in the multiple exemplar than the single exemplar condition ($t(9) = -5.7$, $p < .001$).

In addition, for each participant group we conducted planned comparisons of the number of correct selections against chance for all conditions. It was found that children in the ASD group made the correct selections significantly more often than would be expected by chance in the single exemplar condition ($t(9) = 3.4$, $p = .008$), and the multiple exemplar condition ($t(9) = 2.4$, $p = .038$). Children in the typical group did not make a correct selection significantly more often than would be expected by chance in the single exemplar condition ($t(9) = 0.9$, $p = .373$), but they did so in the multiple exemplar condition ($t(9) = 9.9$, $p < .001$).

In addition, while there was a trend for ASD participants of performing better than typical participants in the single exemplar condition ($t(18) = 1.9$, $p = .077$), they performed significantly worse in the multiple exemplar condition ($t(18) = -2.6$, $p = .023$)

Participant group differences in inhibition ability and working memory

In order to see whether the differences in the structural alignment task can be explained by differences in inhibition ability or general executive function ability, t-tests were carried out for both the inhibition tasks and the working memory task. There was no significant difference in performance between participant groups on any of the tasks: the Grass / Snow inhibition task: ASD M = 9.7, SD = 1.9; Typical M = 10.5, SD = 3.4 ($t(18) = -1.7$, $p = .521$); Knock / Tap inhibition task: ASD M = 10.3, SD = 2.4; Typical M = 9.8, SD = 2 ($t(18) = 1.5$, $p = .619$); Stationary Cups working memory task: ASD M = 11.7, SD = 2.5; Typical M = 11.3, SD = 2.4 ($t(18) = 0.4$, $p = .72$).

6.4. Discussion

The present study investigated whether young children with autism make use of structural alignment processes to the same extent as typically developing children when constructing categories. To investigate this the extent to which their category formation benefited from seeing multiple exemplars of the category was assessed. Children with and without autism were shown both single and multiple exemplars of object categories and asked to extend the novel name given to the objects to either an object which was more perceptually similar to the exemplar/s or correctly to an object which was more conceptually similar, e.g. one which shared the same function with the original object/s.

It was found that, as expected from previous findings (Gentner & Namy, 1999; Chapter 5 of the current thesis), typically developing children showed substantial improvement in their noun (and therefore category membership) extensions when they were shown multiple exemplars compared to when they saw only a single exemplar. This was evidenced by a significantly higher percentage of noun extensions to the taxonomic match when multiple exemplars were presented. In addition, seeing multiple exemplars allowed typically developing children to make correct extensions more often than would be expected on the basis of chance alone. It is highly unlikely that the difference in performance between the single and multiple exemplar condition was due to a practice effect, as the same condition difference was found in Chapter 5 using a large sample of children of the same age range using a between-subjects design i.e. performance was significantly higher in the multiple exemplar condition even when participants had not experienced the single exemplar condition first. Furthermore, responding did not differ significantly between the first and second half of trials within each condition for either participant group. As no practice effect is evident within conditions, this further suggests that it is very unlikely that one would exist between the two conditions.

Children from the ASD group on the other hand did not benefit from the presentation of multiple exemplars. They were no more likely to extend nouns (and therefore category membership) to the taxonomic match if they had seen multiple exemplar than if they had seen only one exemplar. However it should be noted that children with autism did make correct extensions more often than would be expected by chance when they saw either a single or multiple exemplars.

Regarding the main aim of our study, namely to determine whether young children with autism engage in structural alignment in their formation of categories, our findings suggest that they do not. If they were making use of structural alignment processes then they, like the typically developing group, would have shown a substantial improvement in correctly extending novel nouns / category membership when viewing multiple exemplars. Furthermore we did not find that participants in the ASD group differed from those in the typical group in their inhibition ability or working memory ability. This suggest that differences in propensity to engage in structural alignment between ASD and typical children cannot be explained by underlying differences in inhibition ability, working memory, or executive function ability in general. Secondly, we have provided support to the claims that children with autism are capable of constructing categories, although perhaps via different processes to typically developing children.

So our findings suggest that young children with autism may not engage in structural alignment in their formation of categories, but why might this be? When we consider the components of structural alignment and previous conclusions about the problems of autism, the reasons become clearer. Structural alignment is considered to be a way in which young children are able to move away from more perceptually focused means of constructing categories towards a more adult-like understanding, namely that categories are usually made up of things which are conceptually similar, e.g. share a common function. Gentner & Markman's (1997) study into analogical comparison suggest that comparisons of perceptual information can lead to a focus on deeper conceptual information, like relationships between objects. Gentner & Namy (2006) argue that comparison and thus structural alignment can be initiated by giving two objects the same name, i.e. the idea that words are invitations to compare. This was demonstrated in two studies, the first of which, Gentner & Namy (1999) used the same procedure to the one used in the current study to demonstrate that 4-year-old children's extension of category membership shifted towards using shared relations as a basis when they experienced two exemplars of a category labelled with the same novel noun. Furthermore Namy & Gentner (2002) demonstrated that children's behaviour changes if the two exemplars are not labelled with the same, but with two different novel names. In that case, 4-year-olds extended one of the nouns to the perceptually similar item as the exemplar over an item which was perceptually dissimilar, but conceptually belonged to the same category. This research suggests that structural alignment involves a focus shift from perceptual to relational information through comparison. Children do not simply see the two exemplars and see the relational similarities, rather they see the perceptual similarities and this is what highlights the deeper relational commonalities.

We propose that the reason that young children with autism may not engage in structural alignment in their formation of categories is because it involves processes that they tend to struggle with. Firstly, it has been suggested that moving away from sensory patterns, which are concrete and literal, towards more abstract concept formation and an understanding of function may be difficult for individuals with autism (Bogdashina, 2005). A similar shift from concrete to abstract concepts would likely be required when moving from extending category membership on the basis of perceptual similarity towards extending on the basis of conceptual similarity (e.g. function). Secondly, the initial step of structural alignment involves attending to relevant perceptual similarities and according to (Bogdashina, 2005) identifying which are the relevant stimuli which should be attended to may prove difficult for those with autism.

Thirdly, individuals with autism may have a narrow attentional focus resulting in them perceiving only particular stimuli as being related and ignoring all other stimuli outside of current attentional focus (Murray, 1992). This could cause problems in comparison processes, if children with autism are not noticing all of the relevant features or seeing related features as being related. In addition, as structural alignment involves first of all noticing perceptual similarities and then shifting focus onto relational similarities, a narrow attentional focus may lead to further problems; if children with autism focused their attention initially on perceptual similarities (as would be expected as the first step of structural alignment) they may then ignore other stimuli outside of their attentional focus, e.g. relational similarities, thus making it difficult to make the shift in focus from perceptual similarities to relational similarities necessary in structural alignment. If, in addition, as Lovaas and Schreibman (1971) claim, children with autism only attend to a single relevant cue when learning, then this would further suggest a restricted focus of attention. Such a restricted focus would clearly also cause problems for shifting focus between perceptual and relational similarities in structural alignment. However we can provide no evidence that children in the ASD group focussed strongly on perceptual features to support the idea that once attention was focused on perceptual similarities, this is where it stayed.

A more overall theoretical explanation for children with autism's apparent inability to engage in structural alignment could be the idea that they have weak central coherence. The weak central coherence theory (Frith, 1989; Frith & Happe, 1994; Happe, 1999) suggests that individuals with autism have difficulty bringing information together in order to extract higher level meaning. More specifically, unlike typically developing individuals, in a similar vein to the idea of a narrow attentional focus suggested by Murray (1992), those with autism are suggested to be biased towards engaging in detail focused processing, perceiving and retaining features at the expense of overall configurations and contextualised meaning (Frith, 1989, Happe, 1999). Happe (1999) suggests that children with autism will show difficulties with tasks requiring global meaning recognition or contextualised stimuli integration, and presents evidence from various domains to support this claim. In our experimental task this difficulty with integrating stimuli may provide a potential means for understanding why children with autism did not appear to engage in structural alignment. This could have occurred at two levels. Firstly they may have had difficulty drawing together the two exemplars to make the comparison necessary for structural alignment to occur, and secondly, they may have been unable to make the link / transition between the initially noticed perceptual similarities and the deeper relational similarities, in order to arrive at the correct decision to extend the noun on the basis of relational similarity.

One consequence of a weak central coherence in autism is, as Happe (1999) states, the problem of connecting words with objects. According to Gentner, words in the present paradigm are invitations to compare. That is, when the typically developing children heard the two exemplars labelled with the same novel noun then this might have prompted the act of comparison of perceptual features and subsequent structural alignment. When children with autism heard the two exemplars labelled with the same novel noun, then this might not have prompted comparison in the same way as for typically developing children. This would have resulted in the autistic participant performing similarly whether they saw a single or multiple exemplars, which is what they did.

It is important to note that the picture cards used for the single exemplar condition of the structural alignment task were completely different from those in the multiple exemplar condition. Participants therefore never see the same exemplars / category in both a single and multiple exemplar trial. This therefore rules out the possibility that participants simply remembered how they had responded in the single exemplar trial and responded the same in the multiple exemplar trial.

A possible explanation for our finding that unlike typically developing children, those with autism performed above chance in both the single and multiple exemplar conditions might be that this results from the higher chronological age of the children in the ASD group. The average age of the ASD group was 10 months older than that of the typical group. This may have resulted in the children from the ASD group having more experience with categories than those in the typical group and therefore a greater understanding that the objects presented in the task make up some sort of category. They may have had greater experience that categories tend to be made up of objects with a shared function and used this knowledge to guide their choices.

Our findings support the conclusion of early findings (Tager-Flusber, 1985a; Tager-Flusber, 1985b; Ungerer & Sigman, 1987) that individuals with autism are indeed capable of learning categories. But they also support the argument of Gastgeb, Strauss, and Minshew (2006) that the underlying processes of categorisation may be different in individuals with autism. They do not seem to form prototypes of categories (Plaisted, 2000; Klinger &

Dawson, 2001) and do not seem to use structural alignment, both processes that are beneficial to typically developing children when forming categories.

We further suggest that weak central coherence may serve as an overall means for explaining why individuals with autism may engage in alternative processes in the formation of their categories. As already discussed above, weak central coherence would make engaging in structural alignment difficult. But it can also explain other results with regards to categorisation. As suggested by Klinger & Dawson (2001), it would also make the formation of prototypes difficult. The formation of prototypes involves drawing information from multiple exemplars together into a coherent whole and extending that information to new instances. This is exactly the kind of process that would prove problematic for someone with weak central coherence. Rather, a detail-focused approach, as would be involved in using a set of necessary and sufficient rules would play to the relative strengths of someone with weak central coherence. In addition, weak central coherence could help explain why formation of categories proved more difficult for individuals with autism when it moved beyond the categorisation of simple and typical objects, as found in Gastgeb, Strauss, and Minshew (2006). More complex categorisation may require the drawing together of more information or features. Also, difficulty drawing together multiple dimensions may help to explain why the autistic participants in Bott, et al. (2006) based their categories on fewer dimensions than typically developing participants.

Weak central coherence theory has been proposed not necessarily as a cognitive deficit, but rather as a different cognitive style (Happe, 1999). It is possible that this different cognitive style may lend itself towards a different language learning style. The way in which individuals with autism construct categories may be an example of this different language learning style. While it is important to establish the capabilities of individuals with autism, simply finding that they can do something does not necessarily mean that they do so in the same way, i.e. it may not provide the whole picture.

In conclusion, we have attempted to investigate whether children with autism engage in structural alignment in their formation of categories. We have found that they appear to not make use of this process in the same way as typically developing children. Our findings further add to the generally held consensus that while individuals with autism are capable of forming categories they are likely to do so via different processes to those employed by typically developing people. We suggest weak central coherence as a possible explanation for why this is the case.

CHAPTER SEVEN

SUMMARY AND CONCLUSIONS

The overall aim of the present thesis was to conduct an investigation into the difficulty which may accompany children letting go of previously effective word learning strategies. More specifically, the thesis was concerned with how young children overcome an early tendency to focus on perceptual features as a basis for word meaning. In addition the potentially greater difficulty young children may face when attempting to link words to relational concepts was considered. These two aims were explored through studies which made use of a variety of different word types. While the various findings and how they relate to existent literature are discussed within the general discussion section of each chapter, a summary of the findings is presented here.

7.1. Chapter 2

In Chapter 2 we aimed to explore if certain words were truly more difficult for young children to acquire because of their relational nature or if it was rather their dynamic nature that caused the difficulty. In other words, just what is the word learning problem that needs to be overcome: dealing with relational words or dealing with dynamic words? This is an important question as the relational nature of a word (i.e. non-relational or relational) and whether it is static or dynamic tend to be confounded. For example, nouns tend to be both static and non-relational while verbs tend to be both dynamic and relational. We therefore made use of a word type for which this confound does not exist: noun-noun compounds. Noun-noun compounds can possess relational components that can be either static or dynamic. And it is the relation which defines the compound, not the perceptual features of the constituent objects.

It was found that as children aged, what they chose to base their compound-noun extensions on shifted. The youngest participants (2-year-olds) based their extensions on shared perceptual features. This gradually shifted with age towards extensions based on a shared relation between constituent objects, with 4-year-olds being the youngest age group to do so consistently. We have therefore provided evidence for a relational shift in compound-noun learning. That is, as children age they shift their focus away from perceptual features and towards relational features as their basis for noun-noun compound meaning. Noun-noun compounds therefore appear to be challenging for young children to acquire because they are defined primarily by relational components. It is in linking words to relations that young children are having difficulties. In contrast we did not find that any age-groups' choice to base their compound-noun extensions on shared relations was affected by whether the relation was static or dynamic. We therefore found no evidence that compound-nouns linked to more dynamic referents were more difficult to acquire.

Our findings add support to literature suggesting that understanding the importance of the relational component of noun-noun compound meaning in its definition is acquired gradually (e.g. Nicoladis, 2003; Krott et al., 2009; 2010). In terms of the original question regarding whether it is truly the relational nature of certain words which makes them more difficult to acquire or rather their dynamic nature, our findings suggest that it is indeed the relational nature of certain words which constitutes the word learning problem. While the study described in Chapter 2 focuses on noun-noun compounds, what we are interested in is word learning in general. Compound-nouns were used as a tool to separate out the potential influences of relational and dynamic factors. The fact that these two factors are not confounded in compound-nouns, as they are in nouns and verbs has allowed us to do this. We therefore extend our finding to the realms of verb and noun learning. It has been widely found that verbs are more challenging for children to acquire than nouns (e.g. Genter, 1982; for a recent review see Waxman et al., 2013). But verbs are both relational and dynamic in nature, compared to nouns which are both non-relational and static. Due to this confound it has been difficult to determine if it is the relational or dynamic nature of verbs which is causing the difficulty. Our findings with compound-nouns seek to provide an answer to this question. We found that with compound-nouns the difficulty lay in linking a word to a relation and that the static or dynamic nature of said relation had no effect. We therefore suggest that this is likely also the case for verb learning. It is the relational nature of verbs that poses a difficulty for young children, not their dynamic nature. A difficulty with linking words to relations may constitute a general word learning problem across word types, which is overcome with age as children undergo a relational shift in what they choose to base the word extensions on.

This idea of a general word learning problem which is overcome with age as children undergo a relational shift in focus can also be linked to findings from the shape bias literature. The shape bias refers to findings that when required to extend novel nouns on the basis of either shape or function young children tend to choose shape (Gentner, 1978; Merriman, Scott, & Marazita, 1993; Smith, et al., 1996; Graham, Williams, & Huber, 1999). Again please note that children have shown themselves to be capable of extending nouns on the basis of features other than shape under the right circumstances, for example experiencing the function themselves (e.g. Booth, Waxman, & Huang, 2005; Booth & Waxman, 2002; Kemler Nelson, 1999; Kemler Nelson, Russell, Duke, & Jones, 2000). We are referring to instances where children are given minimal exposure to and interaction with referents. As children overcome the shape bias they are shifting their focus away from a static non-relational aspect (shape) towards a dynamic relational aspect (function) but again these aspects are confounded. Our finding with compound-nouns suggest that it is likely relational, rather than dynamic aspects that are preventing younger children from extending nouns on the basis of function.

Our findings from Chapter 2 offer further insight into how young children overcome an early tendency to focus on perceptual features as a basis for word meaning. It appears that a major factor in this early tendency to focus on perceptual features is the difficulty young children have with linking words to relations. We suggest that linking words to relations is a major component in children’s difficulty with using function as a basis for noun meaning and their greater difficulty in acquiring verbs compared to nouns, as well as understanding that compound-nouns are primarily defined by relations. We suggest that children undergo a relational shift in focus during the preschool years which allows them to overcome their early tendency to base their word extensions on perceptual features. This relational shift is strongly evident in the findings of Chapter 2. This is not to say that this is the only factor why, for instance, verbs are more difficult to acquire than nouns, only that it is a contributing factor.

A small caveat is that we are drawing conclusions regarding noun and verb learning from findings using noun-noun compounds. We have not directly tested nouns and verbs in Chapter 2. Future research could attempt to more directly test nouns and verbs to ensure that the explanations provided here are truly applicable to those word types. However the reason for using noun-noun compounds is that relational and dynamic aspects are confounded in nouns and verbs. This is therefore a difficulty which would need to be overcome to directly test nouns and verbs, and one which would not be easily overcome as it is inherent in the nature of the word types.

7.2. Chapter 3

In Chapter 3 we aimed to explore if highlighting the relational component of novel noun-noun compound meaning at encoding would lower the age at which young children recognised its importance in defining the compound. It was found that whether the relational component was highlighted or not, the ability to correctly select the object-pair which shared the same relation, and thus the understanding of the importance of the relation in defining compounds improved with age. However when the relational component was highlighted children were able to make these correct selections at a younger age (age 3). Therefore making the relation explicit did have the effect of lowering the age at which children were able to base their extensions on it.

These finding add to those in the noun-learning literature that demonstrate that the ‘shape bias’ in early noun learning can be overcome by highlighting other more relevant bases for meaning, e.g. function (Kemler Nelson, 1995; Kemler Nelson, 1999; Kemler Nelson, Russel, Duke, & Jones, 2000; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Diesnedruck, Markson, & Bloom, 2003). Tying these findings back to the central aims of this thesis it appear that while young children’s focus appears to be on perceptual features / similarity as their basis for word extensions, explicitly highlighting alternative / more appropriate bases for word extension can lower the age at which children use these more appropriate bases. However it should be noted that even when the relational component was highlighted the youngest age group (2-year-olds) still did not make use of the relation in their extensions. It appears that the focus on perceptual features is particularly strong and difficult to overcome in the youngest children. It highlights that linking words to relational components is very difficult for two-year-olds. It would be interesting in future research to investigate the extent to which highlighting relational components of other word types allows children to recognise their importance in word meaning. Perhaps providing greater emphasis on the action (i.e. relational component) of transitive verbs at encoding would aid younger children in their learning.

7.3. Chapter 4

In Chapter 4 we explored whether structural alignment processes that have been shown to be so helpful in category learning (e.g. Gentner & Namy, 1999; Namy & Gentner, 2002; Gentner & Namy, 2006) could also provide benefit to verb learning. It was found that 5-year-olds could correctly extend a novel verb after viewing only one exemplar, but did perform better having viewed two. Three-year-olds on the other hand were unable to correctly extend a novel verb to a scene featuring the same action after viewing only one exemplar, but were able to after viewing two. A second experiment found that the beneficial effect of the multiple exemplars was reduced when more than one dimension was varied in the second exemplar, i.e. object and actor. It was completely eliminated when the multiple exemplars did not vary along any dimensions, i.e. participants viewed the same scene twice.

The findings from Chapter 4 suggest that multiple exemplars and the structural alignment processes they promote are indeed beneficial for verb learning. They provide a means for young children to move past the action-object interaction mapping of verbs suggested by Imai et al., (2005; 2008), instead mapping verbs correctly to the action part of the scene only. These findings also suggest that for multiple exemplars to be maximally effective in verb learning they should vary along only one dimension. The use of structural alignment provides another means for young children to overcome their difficulty with linking words to relational components. The 3-year-olds in the single exemplar condition of the study in Chapter 4 were engaging in action-object interaction mapping because they appeared to think that for a scene to constitute an example of a verb it must feature both the action which was present when the originally heard the verb and also the object. They were unable to map the verb to the action component only. What structural alignment did was allow them to detach from this false belief that verbs should be mapped to a combinations of action and object. Future research should aim to explore the reason for the difference between our findings and those of Maguire et al. (2008). Our study found that varying exemplars along a single dimension produced the most benefit and simply repeating the same information provided no significant benefit. Maguire et al. (2008) on the other hand found that repeating the same information in multiple exemplars was beneficial, but varying information was not. Clearly it is important to establish the reason behind these differing findings. As our study found no benefit to repetition of the same information with only one additional exemplar whereas Maguire et al. (2008) found beneficial effects with six repetitions, it would be interesting in future studies to assess how many presentations of the same exemplar might be necessary to provide a beneficial effect.

7.4. Chapter 5

In Chapter 5 we investigated whether there is an inhibitory component to structural alignment. That is, do children need to inhibit a prepotent tendency to extend category membership on the basis of perceptual similarities? Results found that correct extension of novel nouns occurred more often when participants had viewed multiple exemplars for all age-groups tested (3- to 5-years). While still improving the performance of 5-year-olds, multiple exemplars were of greatest benefit to 3- and 4-year olds where they elevated performance to above chance level. Therefore all of the age-groups tested were able to make use of structural alignment processes. In addition performance on the inhibition task was found to be associated with the ability to make use of structural alignment. These findings therefore demonstrate that children are able to benefit from structural alignment in their construction of categories from as young as 3-years of age, extending the findings that Gentner & Namy (1999) originally demonstrated with 4-year-olds to a younger age group. Furthermore inhibiting a prepotent tendency to extend category membership on the basis of shared perceptual features does indeed appear to be a part of engaging in structural alignment.

In terms of the overarching aims of this thesis, these findings further suggest that in order to move on to a more adult-like word leaning strategy of extending words on the basis of, for example, shared function in case of nouns and shared actions only in the case of verbs, that young children need to actively inhibit their pre-existing tendency to extend words on the basis of shared perceptual features. In addition, the difficulty young children appear to have with linking words to relational components may be partially explained by this competing tendency to link words to perceptual features. Children may not be able to overcome this tendency until their inhibition abilities have matured.

Future research could further explore this potential association between shifting away from a focus on perceptual features / similarity as a basis for extending word meaning and maturation of inhibition abilities. The extent to which overcoming the shape bias by extending nouns on the basis of function is associated with inhibition ability could be one possible avenue of exploration. As could the extent to which ability to link verbs to the action component of dynamic action scenes is associated with inhibition ability. Results of these potential studies would add to the findings of Chapter 5 to give a more complete picture of the extent to which letting go of perceptual similarity as the primary basis for word meaning is associated with inhibition ability.

7.5. Chapter 6

In Chapter 6 we investigated whether young children with autism engaged in structural alignment in their formation of categories. This was achieved by testing both children with autism and typical children using the same experimental task used in Chapter 5. Results found that unlike typically developing children, children with autism showed no benefit from seeing multiple exemplars in their noun / category extensions. They therefore do not appear to have been engaging in structural alignment in their formation of categories.

The findings from Chapter 6 add support to existing research which suggests that individuals with autism do not form categories in the same way as typically developing individuals (e.g. Plaisted, 2000; Klinger & Dawson, 2001). In addition, in Chapter 6 we propose that the weak central coherence theory (Frith, 1989; Frith & Happe, 1994; Happe, 1999) can explain why individuals with autism construct their categories in a different way to typical individuals. Drawing these findings back to the central aims of this thesis, in not making use of structural alignment processes children with autism may be missing a strong means of moving beyond a word-learning strategy of extending words on the basis of shared perceptual features. As stated previously, structural alignment processes provide a way for children to move towards a more adult-like way of extending words and if children with autism are unable to make use of this then they may have a harder time moving their focus away from perceptual features. However, as the findings from the autistic category learning literature show, even if individuals with autism cannot make use of certain processes that typically developing individuals do (e.g. prototypes, structural alignment) they will use alternative processes that get them to the same end goal. They are therefore able to overcome a potentially greater difficulty with linking words to relational components through their use of alternate strategies which play to the strengths of their different cognitive style (e.g. weak central coherence theory: Frith, 1989; Frith & Happe, 1994; Happe, 1999). One possible example of this is the use of a rule based approach to category formation, as suggested by Klinger & Dawson (2001).

The generalisability of these finding is slightly limited by the small sample size. Future research should seek to further investigate the extent to which the different cognitive style suggested by weak central coherence theory also lends itself to a different language learning style. While individuals with autisms clearly learn language, do they do so via the same processes as typically developing individuals? Identifying the alternate ways in which individuals with autism learn language could help to tailor teaching programs to play to their strengths and thus improve their learning experience.

7.6. Conclusion

In conclusion this thesis has found that one of the potential reasons for young children choosing to focus on perceptual features as their basis for word meaning, even in instances where this is not particularly helpful (e.g. verb learning), is that they may have a greater difficulty in linking words to relations. The current thesis suggests that children may undergo a relational shift in their word learning focus during the preschool years. As opposed to simply getting better with age, they appear be making a qualitative shift in what they choose to base their word extensions on. This shift allows children to overcome their early word learning style of extending words on the basis of perceptual similarity. Furthermore actively highlighting a more appropriate base for word meaning (e.g. the relational component of a compound-noun) can aid children in shifting their focus away from perceptual features, even lowering the age at which they can successfully encode the meaning of certain word types (e.g. noun-noun compounds). This thesis also provides further support for structural alignment as a means for allowing children to move beyond basing word meaning on perceptual features, demonstrating its benefit in helping children to understand that it is the action only which defines a verb and not a combination of the action and a particular object. The current thesis also suggests an inhibitory component to moving beyond basing word meaning on perceptual features. It appears that as this is a word learning strategy that has worked in the past, children may need to inhibit it in order to make use of more appropriate word learning strategies. Finally this thesis suggests that children with autism may not make use of some of the processes employed by typically developing children to overcome this early tendency to focus on perceptual features as a basis for word meaning; in particular structural alignment.

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APPENDICES

APPENDIX A

Novel objects used in Chapter 2 & 3 experiments

APPENDIX B

Object-pairs used in Chapter 2 & 3 experiments

APPENDIX C

Trial sequence of Experiment 1 in Chapter 4

APPENDIX D

Pictures used in both conditions of Structural alignment task in Chapter 5 and multiple exemplar condition of Chapter 6

APPENDIX E

Pictures used in single exemplar condition of Structural alignment task in Chapter 6

APPENDIX A

Novel objects used in Chapter 2 & 3 experiments

Kig: Small hollow plastic shape filled with purple (orange for version 2) plasticine, with yellow plastic circles stuck to the outside.

Donka: Game pen which consisted of a pen with a clear plastic container attached to the end, with red (blue for version 2) play-doe covering the nib and pen logo.

Rinta: Shape made out of blue (red for version 2) play-doe.

Dax: Pink glue spreader (version 2 had yellow pipe-cleaner tied around neck).

Koba: Four coloured straws (two green & two orange for version 1 and two green and two purple for version 2) glued into a piece of yellow (black for version 2) play-doe.

Sav: Orange (yellow for version 2) card covered toothpaste box, with one pyramid shaped end and one end left open. Four circular holes were cut into top.

Tidgy: Shape made of green and yellow (white and red for version 2) plasticine.

Mov: Cereal bar box covered in blue (green for version 2) card with green (pink for version 2) scrunched-up paper glued to sides and two shapes cut out of front.

Coodle: Shape made out of blue (red for version 2) play-doe.

Tez: Orange (blue for version 2) hollow spiky ball.

Wug: Pink (blue for version 2) painted cotton wool ball.

Binto: Glitter pipe with blue (orange for version 2) card triangle sticking out one end (and red pipe-cleaner wrapped around the middle for version 2).

APPENDIX B

Object-pairs used in Chapter 2 & 3 experiments

Kig donka: HAS relation: *Kig* glued to side of *donka*; FOR relation: Top was taken off *donka*, *kig* placed inside, and top replaced.

Wug binto: HAS relation: *Wug* glued to side of *binto*; FOR relation: *Binto* was used to push *wug* along.

Koba sav: HAS relation: Straws of *koba* sticking out of holes of *sav*; FOR relation: *Koba* was placed in side of *sav*.

Tidgy mov: HAS relation: *Tidgy* glued to top of *mov*; FOR relation: *Tidgy* was pushed into frontal hole of *mov*.

Rinta dax: HAS relation: *Rinta* glued to end of *dax*; FOR relation: *Dax* rolled over *rinta*.

Coodle tez: HAS relation: *Coodle* glued to side of *tez*; FOR relation: *Tez* covered and enveloped *coodle*.

N.B. For the HAS relation object-pairs the constituent objects were assembled before the experiment began i.e. participants did not see them being assembled. For the FOR relation object-pairs the constituent objects were combined in front of the participants (i.e. their function was demonstrated).

APPENDIX C

Trial sequence of Experiment 1 in Chapter 4

Participants in the single exemplar condition were exposed to first standard as well as first and second test video. Participants in the multiple exemplar conditions were exposed to first and second standard and first and second test video.

Trial 1

First standard: A woman is rolling object 1 between the palms of her hands.

Second standard: A woman is rolling object 3 between the palms of her hands.

First test video: A woman is lightly tossing and catching object 1 with both hands.

Second test video: A woman is rolling object 2 between the palms of her hands.

Trial 2

First standard: A woman is holding object 3 behind her back, moving it up and down.

Second standard: A woman is holding object 2 behind her back, moving it up and down.

First test video: A woman is holding object 1 behind her back, moving it up and down.

Second test video: A woman is holding object 3 in front with both hands, twisting her torso from side to side.

Trial 3

First standard: A woman is holding object 2 in her right hand and pushing it outward with a punching motion.

Second standard: A woman is holding object 1 in her right hand and pushing it outward with a punching motion.

First test video: A woman is holding object 2 in her right hand and tapping it against her left shoulder.

Second test video: A woman is holding object 3 in her right hand and pushing it outward with a punching motion.

Trial 4

First standard: A woman is holding object 1 in her right hand with her arm stretched straight out above her head then swings it downwards to touch her left knee.

Second standard: A woman is holding object 3 in her right hand with her arm stretched straight out above her head then swings it downwards to touch her left knee.

First test video: A woman is holding object 2 in her right hand with her arm stretched straight out above her head then swings it downwards to touch her left knee.

Second test video: A woman is holding object 1 in her right hand with her arm stretched out to the right. She then passes it under her right leg to her left hand which she then stretches out to the left.

Trial 5

First standard: A woman is holding object 3 in her right hand with her arm held outstretched in front of her held at a 90 degree angle. She then straightens her arm.

Second standard: A woman is holding object 2 in her right hand with her arm held outstretched in front of her held at a 90 degree angle. She then straightens her arm.

First test video: A woman is holding object 3 in her right hand and tapping it against her right knee, which she is raising at the same time as she is lowering the object.

Second test video: A woman is holding object 1 in her right hand with her arm held outstretched in front of her held at a 90 degree angle. She then straightens her arm.

Trial 6

First standard: A woman is passing object 2 around her waist.

Second standard: A woman is passing object 1 around her waist.

First test video: A woman is passing object 3 around her waist.

Second test video: A woman holds object 2 in her left hand out in front of her and drops it into her outstretched right hand.

APPENDIX D

Pictures used in both conditions of Structural alignment task in Chapter 5 and multiple exemplar condition of Chapter 6

Exemplar 1 = E1; Exemplar 2 = E2; Perceptual match = PM; Taxonomic match = TM

Set 1

E1: Apple; E2: Pear; PM: Balloon; TM: Banana

Set 2

E1: Plate; E2: Bowl; PM: Cookie; TM: Casserole Dish

Set 3

E1: Drum; E2: Tambourine; PM: Hat Box; TM: Flute

Set 4

E1: Carrot; E2: Corn; PM: Rocket; TM: Turnip

Set 5:

E1:Ice Cream; E2: Lollipop; PM: Top; TM: Chocolate Bar

Set 6

E1: Baseball Cap; E2: Cowboy Hat; PM: Igloo; TM: Sombrero

Set 7

E1: Bicycle; E2: Tricycle; PM: Glasses; TM: Skateboard

Set 8

E1: Caterpillar; E2: Snake; PM: Rope; TM Turtle

Set 9

E1: Baseball Bat; E2: Golf Club; PM: Pencil; TM: Tennis Racket

Set 10

E1: Baseball; E2: Beach Ball; PM: Orange; TM: Football

APPENDIX E

Pictures used in single exemplar condition of Structural alignment task in Chapter 6

Exemplar = E; Perceptual match = PM; Taxonomic match = TM

Set 1

E: Hammer; PM: Cross; TM; Saw

Set 2

E: Guitar; PM: Squash; TM; Piano

Set 3

E: Purse; PM: Bean bag; TM: Wallet

Set 4

E: Sock; PM: Balloon (deflated); TM: Shirt

Set 5

E: Shoe; PM: Iron; TM: High heeled boot

Set 6

E: Surf board; PM: Ironing board; TM: Boat

Set 7

E: Mobile phone; PM: Bar of soap; TM: House phone

Set 8

E: Oak tree; PM: Candyfloss; TM: Birch tree

Set 9

E: Triangle shaped sandwich; PM: Pyramid; TM: Beef burger

Set 10

E: Clock; PM: Wheel; TM: Square faced watch